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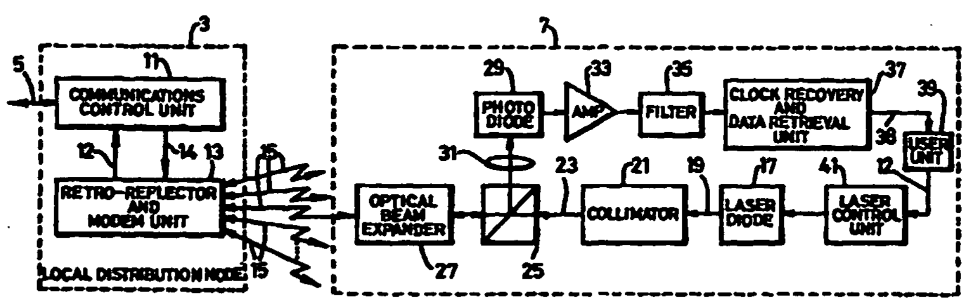

(57) Abstract

A point to multipoint signalling system is provided between a first signalling device and a plurality of second signalling devices. The first signalling device comprises means for receiving signals transmitted from the plurality of second signalling devices, means for modulating the received signals with respective modulation data for the second signalling devices and means for reflecting the modulated signals back to the respective second signalling devices. Each second signalling device comprises means for generating a signal, means for transmitting the generated signal to the first signalling device, means for receiving the modulated signal which is reflected back from the first signalling device and means for retrieving the modulation data from the reflected signal. A retro-reflector and a multipoint to point signalling system are also provided.

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SIGNALLING SYSTEM

The present invention relates to a signalling system. One aspect of the present invention relates to a free space point to multipoint signalling method and apparatus. Another aspect of the invention relates to a retro-reflector for use in a signalling system. According to a further aspect, the present invention relates to a multipoint to point signalling system.

There are a number of existing systems which allow point to multipoint communications. For example, there are existing radio and microwave broadcast systems in which messages are broadcast as radio/microwave signals from a central transmitter to a plurality of remote receivers. However, there are a number of disadvantages with this kind of broadcasting system. One disadvantage is that a large amount of the transmitted power is wasted due to the inevitable broadcasting of the signals into regions where there are no receivers. Another problem with this kind of broadcast system is that there is limited bandwidth (a few Megahertz for radio frequencies and up to one hundred Megahertz for microwave frequencies). Another problem with this kind of broadcast system is that it is subject to regulatory requirements. In particular, the transmission of signals in radio and microwave frequency bands is strictly controlled, with users being required to obtain a licence in order to broadcast.

Another type of known point to multipoint communications system employs cables (optical and/or electrical) and taps/junctions through which communications from a transmitter are passed to multiple receivers. However, these cable systems can be expensive, due to the cost of

the cable itself and its installation, and is not suitable in some situations. In particular, although it may be practical to install cable along most streets, it may not be practical to install the cable from the street into every home and office along the side of the street. Cable systems are also not practical in temporary systems where a short term communications link is required.

Another type of known point to multipoint communication system is an optical broadcast system, in which the messages are broadcast as optical signals from an optical transmitter to a plurality of remote optical receivers. However, as with the radio and microwave broadcast systems, such an optical broadcast system suffers from the disadvantage that a large amount of the transmitted power is wasted due to the broadcasting of the signals into areas where there are no receivers. Additionally, since the power of the transmitted laser beam must meet eye-safety requirements, present systems can only broadcast over short distances of about a few metres.

According to one aspect, the present invention provides an alternative point to multipoint signalling system.

According to this aspect, the present invention provides a point to multipoint signalling system, comprising a first signalling device and a plurality of second signalling devices, wherein the first signalling device comprises: means for receiving signals transmitted from the plurality of second signalling devices, means for modulating the received signals with respective modulation data for the second signalling devices and means for reflecting the modulated signals back to the respective second signalling devices, and wherein each second signalling device comprises: means for generating

a signal, means for transmitting the generated signal to said first signalling device, means for receiving the modulated signal which is reflected back from said first signalling device, and means for retrieving the modulation data from the reflected signal.

The present invention also relates to a retro-reflector for use in a signalling system. Optical retro-reflectors are commonly used in a wide variety of applications from precision metrology to "cats-eye" road markers. The main function of the retro-reflector is to reflect incident light back towards the source. There are currently three different types of optical retro-reflectors commonly in use, namely the spherical reflector, the corner cube reflector and the plane mirror.

Plane mirrors are only effective as optical retro-reflecting elements when they are carefully aligned with the source, so that the reflective surface is orthogonal to the direction of travel of the light emitted from the source.

Corner cube reflectors typically comprise an arrangement of three mutually perpendicular mirrors. Alternatively, they can be constructed from a glass prism with three mutually perpendicular reflecting surfaces formed by the faces of the prism. Light incident on such a corner cube reflector is reflected from all three surfaces and travels back towards the source parallel to its original path. Typically these corner cube reflectors have acceptance angles (i.e. a field of view) of +/-30°, thereby eliminating the need for precise angular alignment with the source.

There are several different forms of spherical retro-

reflectors. The most common comprises a relatively high reflective index sphere which focuses the incident light on the rear surface of the sphere (which can be coated with a reflective coating) where it is reflected back along its original path. This is the basis of the "cats-eye" type reflectors commonly used for road markings. Other types of spherical retro-reflectors comprise of one or more concentric spheres of differing refractive index or reflectivity, with the reflection occurring at the surface of the concentric spheres.

A second aspect of the present invention aims to provide an alternative type of retro-reflector.

According to this aspect, the present invention provides a retro-reflector comprising: a focusing member, having first and second focal planes, for focusing signals received from a source, a stop member, located substantially at said first focal plane, for blocking part of the received signals from said focusing member and a reflecting member, located substantially at said second focal plane, for reflecting said signal back to said source.

The second aspect of the invention also provides a retro-reflector comprising a telecentric lens for receiving and focusing light from a light source and a reflecting means located substantially at the focal plane of said telecentric lens for reflecting said light back to said light source.

A third aspect of the present invention aims to provide an alternative type of multipoint to point signalling system.

According to this third aspect, the present invention provides a multipoint to point signalling system, comprising a first signalling device and a plurality of second signalling devices located at preselected locations with respect to said first signalling device, wherein each second signalling device comprises: at least one sensor input terminal operable to receive a signal from a sensor and a light source operable to generate a light beam in dependence upon said sensor signal for transmission to said first signalling device and wherein said first signalling device comprises: a plurality of light detectors for detecting light transmitted from the plurality of second signalling devices and means for focusing the light transmitted from each second signalling device onto a respective light detector.

Exemplary embodiments of the present invention will now be described with reference to the accompanying drawings in which:

Figure 1 is a schematic block diagram of a video data point to multipoint communication system;

Figure 2 is a schematic block diagram of a local distribution node and a user terminal forming part of the video and data communication system shown in Figure 1;

Figure 3 is a schematic diagram of a retro-reflecting modulator unit employed in the local distribution node shown in Figure 2;

Figure 4 is a schematic diagram of a pixellated modulator forming part of the retro-reflecting modulator unit shown in Figure 3;

Figure 5a is a cross sectional view of one modulator of the pixellated modulator shown in Figure 4 in a first operational mode when no DC bias is applied to electrodes thereof;

Figure 5b is a cross sectional view of one modulator

of the pixellated modulator shown in Figure 4 in a second operational mode when a bias voltage is applied to the electrodes;

Figure 6 is a signal diagram which illustrates the way in which light incident on a pixel one of the modulators shown in Figure 4 is modulated in dependence upon the bias voltage applied to the pixel electrodes;

Figure 7 is a schematic diagram of a local area network employed in an office environment which has two optical point to multipoint signalling systems;

Figure 8 is a schematic diagram of a data distribution system;

Figure 9 is a schematic diagram of a local distribution node and a user terminal forming part of the data distribution system shown in Figure 8;

Figure 10 is a schematic illustration of a retro-reflecting modulator employed in the local distribution node shown in Figure 9;

Figure 11 schematically illustrates an array of liquid crystal modulators forming part of the retro-reflecting modulator shown in Figure 10;

Figure 12 shows a cross section of a portion of one of the liquid crystal modulators shown in Figure 11;

Figure 13a illustrates the operation of a liquid crystal modulator with no bias potential applied to electrodes thereof;

Figure 13b illustrates the operation of a liquid crystal modulator with an alternating bias potential applied to the electrodes thereof;

Figure 14a is a schematic diagram of an alternative retro-reflecting modulator which may be employed a point to multipoint communication system;

Figure 14b is a perspective view of the retro-reflecting modulator shown in Figure 14a;

Figure 14c is a cross sectional view of a further

alternative retro-reflecting modulator which can be used in a point to multipoint signalling system;

Figure 15a illustrates an alternative type of modulator which can be used in a retro-reflector in a point to multipoint signalling system;

Figure 15b is a signal diagram which illustrates a first mode of operation of the modulator shown in Figure 15a;

Figure 15c is a signal diagram illustrating a second mode of operation of the modulator shown in Figure 15a;

Figure 16a is a schematic diagram of a piezo-electric modulator which can perform phase and frequency modulation to light incident thereon;

Figure 16b is a signal diagram illustrating the way in which phase and frequency modulation is achieved by the modulator shown in Figure 16a;

Figure 17 is a schematic diagram of a retro-reflector and modem unit which uses a beam splitter to split incident laser beams onto a separate modulator array and demodulator array;

Figure 18 is a schematic diagram which illustrates the way in which a micro-lens can be placed in front of a modulator cell so as to increase the collimation of light into the modulator cell;

Figure 19 is a block diagram of a multipoint to point monitoring system; and

Figure 20 is a block diagram which illustrates a local monitoring node and a number of sensor terminals forming part of the monitoring system shown in Figure 19.

Figure 1 schematically illustrates a video broadcast system for supplying video signals, for a plurality of television channels, to a plurality of remote users. As shown in Figure 1, the system comprises a central distribution system 1 which transmits optical video

signals to a plurality of local distribution nodes 3 via a bundle of optical fibres 5. The local distribution nodes 3 are arranged to receive the optical video signals transmitted from the central distribution system 1 and to transmit relevant parts of the video signals to respective user terminals 7 (which are spatially fixed relative to the local distribution node 3) as optical signals through free space, i.e. not as optical signals along an optical fibre path.

In this embodiment, the video data for all the available television channels is transmitted from the central distribution system 1 to each of the local distribution nodes 3, each user terminal 7 informs the appropriate local distribution node 3 which channel or channels it wishes to receive (by transmitting an appropriate request) and, in response, the local distribution node 3 transmits the appropriate video data, to the respective user terminals 7. Each local distribution node 3 does not, however, broadcast the video data to the respective user terminals 7. Instead, each local distribution node 3 is arranged (i) to receive an optical beam transmitted from each of the user terminals 7 which are in its locality, (ii) to modulate the received beams with the appropriate video data for the desired channel or channels, and (iii) to reflect the modulated beams back to the respective user terminals 7. In addition to being able to receive optical signals from the central distribution system 1 and from the user terminal 7, each of the local distribution nodes 3 can also transmit optical data, such as status reports, back to the central distribution system 1 via the respective optical fibre bundle 5, so that the central distribution system 1 can monitor the status of the distribution network.

Figure 2 schematically illustrates in more detail the main components of one of the local distribution nodes 3 and one of the user terminals 7 of the system shown in Figure 1. As shown in Figure 2, the local distribution node 3 comprises a communications control unit 11 which (i) receives the optical signals transmitted along the optical fibre bundle 5 from the central distribution system 1; (ii) regenerates the video data from the received optical signals; (iii) receives messages 12 transmitted from the user terminals 7 and takes appropriate action in response thereto; and (iv) converts the appropriate video data into data 14 for modulating the respective light beams 15 received from the user terminals 7. In converting the video data into modulation data 14, the communications control unit 11 will encode the video data with error correction coding and coding to reduce the effects of inter-symbol-interference and other kinds of well known sources of interference such as from the sun and other light sources.

The local distribution node 3 also comprises a retro-reflector and modem unit 13, which is arranged to receive the optical beams 15 from the user terminals 7 which are within its field of view, to modulate the respective light beams with the appropriate modulation data 14 and to reflect the modulated beams back to the respective user terminals 7. In the event that an optical beam 15 received from one of the user terminals 7 carries a message 12, then the retro-reflector and modem unit 13 retrieves the message 12 and sends it to the communications control unit 11 where it is processed and the appropriate action is taken. In this embodiment, the retro-reflector and modem unit 13 has a horizontal field of view which is greater than +/- 50° and a vertical

field of view of approximately +/- 5°.

Figure 2 also shows the main components of one of the user terminals 7. As shown, the user terminal 7 comprises a laser diode 17 for outputting a laser beam 19 of coherent light. In this embodiment, the user terminals 7 are designed so that they can communicate with the local distribution node 3 within a range of 150 metres with a link availability of 99.9 per cent. To achieve this, the laser diode 17 is a 50 mW laser diode which outputs a laser beam having a wavelength of 850 nm. This output laser beam 19 is passed through a collimator 21 which reduces the angle of divergence of the laser beam 19. The resulting laser beam 23 is passed through a beam splitter 25 to an optical beam expander 27, which increases the diameter of the laser beam for transmittal to the retro-reflector and modem unit 13 located in the local distribution node 3. The optical beam expander 27 is used because a large diameter laser beam has a smaller divergence than a small diameter laser beam. Additionally, increasing the diameter of the laser beam also has the advantage of spreading the power of the laser beam over a larger area. Therefore, it is possible to use a higher powered laser diode 17 whilst still meeting eye-safety requirements.

Using the optical beam expander 27 has the further advantage that it provides a fairly large collecting aperture for the reflected laser beam and it concentrates the reflected laser beam into a smaller diameter beam. The smaller diameter reflected beam is then split from the path of the originally transmitted laser beam by the beam splitter 25 and focused onto a photo-diode 29 by a lens 31. Since the operating wavelength of the laser diode 17 is 850nm, a silicon avalanche photo-diode (APD)

can be used, which is generally more sensitive than other commercially available photo detectors, because of the low noise multiplication which can be achieved with these devices. The electrical signals output by the photodiode 29, which will vary in dependence upon the modulation data 14, are then amplified by the amplifier 33 and filtered by the filter 35. The filtered signals are then supplied to a clock recovery and data retrieval unit 37 which regenerates the clock and the video data using standard data processing techniques. The retrieved video data 38 is then passed to the user unit 39, which, in this embodiment, comprises a television receiver in which the video data is displayed to the user on a CRT (not shown).

In this embodiment, the user unit 39 can receive an input from the user, for example indicating the selection of a desired television channel, via a remote control unit (not shown). In response, the user unit 39 generates an appropriate message 12 for transmittal to the local distribution node 3. This message 12 is output to a laser control unit 41 which controls the laser diode 17 so as to cause the laser beam 19 output from the laser diode 17 to be modulated with the message 12. As those skilled in art will appreciate, in order that the data being transmitted in opposite directions do not interfere with each other, different modulation techniques should be employed. For example, if the amplitude of the laser beam 15 is modulated by the local distribution node 3, then the laser control unit 41 should modulate, for example, the phase of the transmitted laser beam. Alternatively, the laser control unit 41 could apply a small signal modulation to the laser beam 19 to create a low-bandwidth control channel between the user terminal 7 and the local distribution node 3. This is possible

provided the detector in the local distribution node 3 can detect the small variation in the amplitude of the received laser beam. Furthermore, such a small signal amplitude modulation of the laser beam would not affect a binary "on" and "off" type modulation which could be employed by the retro-reflector and modem unit 13.

The structure and function of the components in the user terminal 7 are well known to those skilled in the art and a more detailed description of them shall, therefore, be omitted.

Figure 3 schematically illustrates the retro-reflector and modem unit 13 which forms part of the local distribution node 3 shown in Figure 2. As shown, in this embodiment, the retro-reflector and modem unit 13 comprises a wide angle telecentric lens system 51 and an array of modulators and demodulators 53. The design of such a wide angle telecentric lens using fisheye lens techniques is well known to those skilled in the art. In this embodiment, the telecentric lens 51 comprises lens elements 51 and 55 and a stop member 57, having a central aperture 59, which is optically located on the front focal plane 60 of the lens system. The size of the aperture 59 is a design choice and depends upon the particular requirements of the installation. In particular, a small aperture 59 results in most of the light from the sources being blocked (and hence represents a significant transmission loss of the system) but does not require a large expensive lens to focus the light. In contrast, a large aperture will allow most of the light from the sources to pass through to the lens but requires a larger and hence more expensive lens system 61. However, since the overriding issue with free space optical transmission is atmospheric loss, little

is often gained by increasing the size of the aperture 59 beyond a certain amount.

Due to the telecentricity of the telecentric lens 51, the light incident on the lens system 61 is focused at the rear image plane 62 in such a way that the principal rays 63 and 65 which emerge from the lens system 61 are perpendicular to the back focal plane 62. One problem with existing optical modulators is that the efficiency of the modulation, ie the modulation depth, which is performed depends upon the angle with which the laser beam hits the modulator. Therefore, when used with one of the prior art type retro-reflectors described above, the modulation depth depends upon the positions of the user terminals 7 within the retro-reflector's field of view. In contrast, by using a telecentric lens 51 and by placing the modulator and demodulator array at the back focal plane 62 of the telecentric lens 51, the principal rays of the laser beams 15 from the user terminals 7 will all be at 90° to the surface of the modulators, regardless of the positions of the user terminals 7 within the retro-reflector's field of view. Consequently a high efficiency optical modulation can be achieved.

Additionally, as is illustrated by the two sets of rays 67 and 69, laser beams from different sources are focused onto different parts of the array of modulators and demodulators 53. Therefore, by using an array of separate modulators and demodulators, the laser beams 15 from all the user terminals 7 can be separately detected and modulated by a respective modulator and demodulator. Figure 4 is a schematic representation of the front surface (ie the surface facing the lens system 61) of the modulator and demodulator array 53 which, in this embodiment, comprises one hundred columns of

modulator/demodulator cells and ten rows of modulator/demodulator cells (not all of which are shown in the figure). Each modulator/demodulator cell c_{ij} comprises a modulator m_{ij} and a demodulator d_{ij} located adjacent the corresponding modulator. In this embodiment, the size 71 of the cells c_{ij} are between 50 and 200 μm, with the spacing (centre to centre) 72 between the cells being slightly greater than the cell size 71.

The telecentric lens 51 is designed so that the spot size of a focused laser beam from one of the user terminals 7 corresponds with the size 71 of one of the modulator/demodulator cells c_{ij}, as illustrated by the shaded circle 73 shown in Figure 4, which covers the modulator/demodulator cell c_{22}. The way in which the laser beams from the user terminals 7 are aligned with the retro-reflector and the way in which the system initially assigns the modulator/demodulator cells to the respective user terminals will be described in more detail later.

In this embodiment, SEED (self-electro-optic effect devices) modulators 79, developed by the American Telephone and Telegraph Company (AT&T), are used for the modulators m_{ij}. Figure 5a schematically illustrates the cross-section of such a SEED modulator 79. As shown, the SEED modulator 79 comprises a transparent window 81 through which the laser beam 15 from the appropriate user terminal 7 can pass, a layer 83 of Gallium Arsenide (GaAs) based material for modulating the laser beam 15, an insulating layer 85, a substrate 87 and a pair of electrodes 89 and 91 located on either side of the modulating layer 83 for applying a DC bias voltage to the

modulating material 83.

In operation, the laser beam 15 from the user terminal 7 passes through the window 81 into the modulating layer 83. Depending upon the DC bias voltage applied to the electrodes 89 and 91, the laser beam 15 is either reflected by the modulating layer 83 or it is absorbed by the modulating layer 83. In particular, when no DC bias is applied to the electrodes 89 and 91, as illustrated in Figure 5a, the laser beam 15 passes through the window 81 and is absorbed by the modulating layer 83. Consequently, when there is no DC bias voltage applied to the electrodes 89 and 91, no light is reflected back to the corresponding user terminal 7. On the other hand, when a DC bias voltage of approximately 20 volts is applied across the electrodes 89 and 91, as illustrated in Figure 5b, the laser beam 15 from the corresponding user terminal 7 passes through the window 81 and is reflected by the modulating layer 83 back upon itself along the same path to the corresponding user terminal 7.

Therefore, by changing the bias voltage applied to the electrodes 89 and 91 in accordance with the modulation data 14 to be transmitted to the user terminal 7, the SEED modulator 79 will amplitude modulate the received laser beam 15 and reflect the modulated beam back to the user terminal 7. In particular, as illustrated in Figure 6, for a binary zero to be transmitted, a zero voltage bias is applied to the electrodes 89 and 91, resulting in no reflected light, and for a binary one to be transmitted a DC bias voltage of 20 volts is applied across the electrodes 89 and 91, resulting in the laser beam 15 being reflected back from the modulator 79 to the corresponding user terminal 7. Therefore, the light beam

which is reflected back to the user terminal 7 is, in effect, being switched on and off in accordance with the modulation data 14. Therefore, by monitoring the amplitude of the signal output by the photo-diode 29 shown in Figure 2, the corresponding user terminal 7 can detect and recover the modulation data 14 and hence the corresponding video data.

Ideally, the light which is incident on the SEED modulator 79 is either totally absorbed therein or totally reflected thereby. In practice, however, the SEED modulator 79 will reflect typically 5% of the laser beam 15 when no DC bias is applied to the electrodes 89 and 91 and between 20 and 30% of the laser beam 15 when the DC bias is applied to the electrodes 89 and 91. Therefore, in practice, there will only be a difference of about 15 to 25% in the amount of light which is directed onto the photo-diode 29 when a binary zero is being transmitted and when a binary one is being transmitted.

By using the SEED modulators 79, modulation rates of the individual modulator cells m_{ij} as high as 2 Giga bits per second can be achieved. This is more than enough to be able to transmit the video data for the desired channel or channels to the user terminal 7 together with the appropriate error correcting coding and other coding which may be employed to facilitate the recovery of the data clock.

In this embodiment, each of the individual demodulator d_{ij} comprises a photo-diode which is connected to an associated amplifier, filter and clock recovery and data retrieval unit similar to those employed in the user terminal 7 shown in Figure 2, which operate to detect any

modulation of the corresponding laser beam and to regenerate any messages 12 which are transmitted from the corresponding user terminal 7. All the recovered messages 12 are then transmitted back to the communications control unit 11 where they are processed and appropriate actions are taken.

As mentioned above, before a user terminal 7 can communicate with the local distribution node 3, an initialisation procedure must be performed. A brief description of this initialisation procedure will now be given. Upon installation of a new user terminal 7, the installer will manually align the user terminal 7, so that the laser beam will be directed roughly in the direction of the local distribution node 3. The installer will then set the new user terminal 7 into an installation mode in which a laser beam having a wide beamwidth and carrying an initialisation code is output by the new user terminal 7 and directed towards the local distribution node 3. Part of this wide beamwidth laser beam will be received at the local distribution node 3 and will be focused onto an unknown modulator/demodulator cell c_{ij} by the telecentric lens 51. The communications control unit 11 then samples signals from all the unassigned cells until it finds the initialisation code and then assigns that cell to the new user terminal 7 for all future communications. During this initialisation period, the new user terminal 7 will also use the strength of the reflected beam which it receives to control servo motors (not shown) to make fine adjustments in the direction in which the laser beam 15 is being output by the new user terminal 7. After the initialisation has been completed, the new user terminal is set into an operational mode in which a narrow collimated laser beam is produced and transmitted to the

local distribution node 3 for receiving the appropriate modulation data 14.

As the those skilled in the art will appreciate, the point to multipoint signalling system described above has a number of advantages over the prior art point to multipoint signalling systems. These include:

1) the point to multipoint signalling system does not waste optical power by transmitting data into areas where there are no receivers. Additionally, the local distribution nodes 3 effectively only transmit data to those user terminals which are switched on, since a user terminal 7 will not emit a laser beam whilst the corresponding television receiver is switched off.

2) The use of collimated laser beams leads to low transmission losses (which are mainly due to diffraction, the limited collection aperture, modulator losses and atmospheric transmission losses) which allows the use of a low optical power laser diode.

3) A small signal modulation of the collimated laser beam can be used to implement a low-bandwidth control channel from the user terminal 7 to the corresponding local distribution node 3.

4) The optics used in the retro-reflector and modem unit 13 can be designed so that it has a large field of view, since the telecentric lens causes the principal rays from the laser beams to be directed towards the modulator at 90° thereto. Consequently, the problem of angle sensitivity of existing optical modulators can be overcome so that efficient modulation can be achieved.

Figure 7 is a schematic diagram of a local area network 101 employed in an office environment having two point to multipoint signalling systems. As shown, the local area network 101 comprises a data bus 103 which connects

together personal computers 105, printers 107, modem units 109 and mass storage units 111 located throughout the office. A server 113 is provided for controlling the use of the network resources and for maintaining a record of the status of the local area network 101. The data bus 103 is, in this embodiment, also connected via gateway 115 to a wide area network 117. The purpose and function of each of the elements described above is well known to those skilled in the art and will not be described further.

As shown in Figure 7, two local data input/output nodes 119 and 121 are also connected to the data bus 103. In this embodiment, these local data input/output nodes are located in different rooms 120 and 122 respectively and have the same function as the local distribution nodes 3 shown in Figure 1. In particular, local data input/output node 119 is arranged to receive laser beams 123 transmitted from the personal computers 125 and 127, work station 129 and printer 131, to modulate the respective laser beams 123 with appropriate data and to reflect the modulated beams back to the respective source. Accordingly, each of the PCs 125 and 127, the work station 129 and the printer 131 will comprise the circuitry of the user terminal 7 shown in Figure 2, except the user unit 39 will correspond to either the PC 125 or 127, the work station 129 or the printer 131. Similarly, local data input/output node 121 is arranged to receive laser beams 135 transmitted from printer 137, laptops 139 and 141 and a personal computer 143, to modulate the respective laser beams 135 with appropriate data and to reflect the modulated beams back to the appropriate source. In this way, each of the printers 131 and 137, personal computers 125, 127 and 143, laptops 139 and 141 and the work station 129 can transmit data

to and receive data from the local area network 101.

The particular way in which the data is transmitted to and from the local data input/output node 119 is similar to that used in the video data distribution system described with reference to Figures 1 to 6 and will therefore not be described again. However, since the laptops 139 and 141 are designed to be carried about by the user, the positional relationship between the laptops 139 and 141 and the local data input/output node 121 is not spatially fixed. Consequently, the point at which the laser beams from the laptops 139 and 141 hits the modulator (not shown) will change as the user moves the laptop. One way to overcome this problem is to employ a separate transceiver circuit (ie the circuitry shown in the user terminal 7 of Figure 2) which has a fixed positional relationship relative to the local data input/output node 121 and which can be connected to the appropriate laptop 139 or 141 by cable. Alternatively, the array of modulators and demodulators located within the local data input/output node 121 could be operated in unison, wherein each modulator would receive the same modulation data and the signals from the demodulators would be connected together, and wherein each of the devices which are connected to the local data input/output node 121 would share the usage of the modulators in a time multiplexed manner. In this way, it does not matter if the laptops 139 and 141 move with respect to the local data input/output node 121, since their laser beams will always strike one modulator/demodulator cell. However, operating the modulators in unison, has the disadvantage of reducing the amount of data which can be transmitted per second through the local data input/output node 121. Alternatively still, if the spot size of the laser beams

135 were arranged to cover more than one cell c_{ij}, then the position of the laptops can be tracked and therefore, the assignment of the cells to the laptops can be dynamically changed as they move relative to the local data input/output node 121.

Figure 8 schematically shows a data distribution system which employs a point to multipoint signalling system. The data distribution system is similar to the video data distribution system shown in Figure 1, except that data is passed in only one direction, from the central distribution system 1 to the user terminals 7. Such a data distribution system can be employed to distribute information relating to, for example, the prices of shares which are bought and sold on a stock market. In such an application, the individual user terminals 7 would comprise a display unit for displaying the new prices of the stocks to the traders so that they can be kept up-to-date with changes in the share prices. Alternatively, such a one-way data distribution system could be used in railway stations, airports and the like for informing passengers of arrivals and departures etc.

Figure 9 is a schematic block diagram of one of the local distribution nodes 3 and one of the user terminals 7 used in the data distribution system shown in Figure 8. As shown, the local distribution node 3 comprises a communications control unit 11 which is operable to receive the optical data transmitted by the central distribution system 1 via the optical fibre bundle 5, to regenerate the transmitted data and to send appropriate modulation data 14 to the retro-reflector and modulator unit 151. The retro-reflector and modulator unit 151 operates in a similar manner to the retro-reflector and modem unit 13 shown in Figure 3, except that it does not

have any demodulators d_{ij} for receiving communications transmitted from the user terminals 7.

As shown in Figure 9, the user terminal 7 has a similar structure to the user terminal shown in Figure 2, except that there is no optical beam expander 27 in front of the beam splitter 25 and there is no laser control circuit 31 for modulating the laser diode 17 for transmitting messages from the user terminal 7 back to the local distribution node 3. Additionally, in this embodiment, the user unit 39 comprises a display (not shown) which is operable to receive the data 38 output from the clock recovery and data retrieval unit 37 and to display it to the user. The remaining components of the user terminal 7 operate in a similar manner to the corresponding components shown in Figure 2, and will not be described again.

Figure 10, schematically shows the retro-reflector and modulator unit 151 employed in this embodiment. As in the first embodiment, the retro-reflector and modulator unit 151 employs a telecentric lens 51 which comprises a lens system 61 and a stop member 57, having a central aperture 59, which is located at the front focal plane 60 of the lens system 61. In this embodiment, a plane mirror 153 is located at the back focal plane 62 of the lens system 61 and a transmissive modulator 155 is located between the plane mirror 153 and the lens system 61.

In operation, a laser beam 15 from a user terminal 7 passes through the stop member 57 and is focused by the lens system 61 through the transmissive modulator 155, where it is modulated with the appropriate modulation data 14 supplied from the communications control unit 11

shown in Figure 9, onto the plane mirror 153 where the modulated beam is reflected back to the user terminal 7.

In this embodiment, an array of transmissive twisted nematic liquid crystal modulators are used in the modulator 155. Figure 11 schematically illustrates such an array of liquid crystal modulators 156 and the associated drive circuitry employed to drive them. As shown, the array of liquid crystal modulators comprises a plurality of horizontal and vertical transparent electrodes which are disposed on either side of a layer of liquid crystal, with each modulator m_{ij} being formed at the junction of a horizontal electrode H_i and a vertical electrode V_j. The drive signals which are required to change the optical state of the liquid crystal modulator m_{ij} are generated by the horizontal drive circuit 167 and the vertical drive circuit 169, under control of the drive signal generator 161. In particular, in response to the modulating data 14 supplied from the communications control unit 11 shown in Figure 9, the drive signal generator 161 generates control signals 163 and 165 for controlling the horizontal drive circuit 167 and the vertical drive circuit 169 respectively, which in-turn apply appropriate driving signals to drive the appropriate modulator m_{ij}.

Figure 12 shows a cross-section of one of the modulators m_{ij} in more detail. As shown the liquid crystal modulator m_{ij} comprises a layer of twisted nematic liquid crystal 175 which is formed between a transparent horizontal electrode H_i and a transparent vertical electrode V_j. In this embodiment, a polarised filter 177 is located behind the vertical electrode V_j for transmitting light which is horizontally polarised and

for blocking light which is vertically polarised.

The way in which the liquid crystal modulator operates will now be described with reference to Figures 13a and 13b. In particular, Figure 13a schematically illustrates the operation of one of the liquid crystal modulators when no bias voltage is applied to the corresponding horizontal and vertical electrodes (not shown). In this embodiment the light emitted from the laser diode 17 is horizontally polarised. This is represented by the horizontal arrows 171 which approach the liquid crystal layer 175 from the left hand side. When no electric field is applied across the liquid crystal layer 175, because of the twisted nematic molecules, the polarisation of the incident light is rotated through 90°. Consequently, the laser beam which leaves the liquid crystal layer 175 will be vertically polarised, as represented by vertical arrows 172. In this embodiment, the polarised filter 177 is designed to block light which is vertically polarised. Therefore, when no electric field is applied across the liquid crystal layer 175 the light which passes therethrough is blocked by the polarised filter 177.

On the other hand, when an alternating electric field is applied across the liquid crystal layer 175, as shown in Figure 13b, the twisted nematic molecules align with the electric field causing the light to pass through the liquid crystal layer 175 without a change in its polarisation state. Consequently, as illustrated by the arrows 174, the light which emerges from the liquid crystal layer 175 still has a horizontal component (although it may be slightly reduced) which will pass through the polarised filter 177 to the plane mirror 153. Since the reflected beam will also be horizontally

polarised, it will also pass through the polarised filter 177 and through the liquid crystal layer 175 back towards the appropriate user terminal 7.

Therefore, by applying a suitable bias voltage to the appropriate horizontal and vertical electrodes, the liquid crystal modulators m_{ij} can amplitude modulate the laser beam 15 received from the corresponding user terminal 7 in dependence upon the modulation data 14. In particular, to transmit a binary zero no bias voltage is applied to the electrodes, whereas to transmit a binary one an alternating bias voltage is applied to the electrodes.

One advantage of using liquid crystal modulators is that they can be made to operate over a wider range wavelengths of the incident light. Consequently, longer wavelength laser beams, such as 1500nm wavelength lasers, can be used, which are less susceptible to absorbtion by rain. Use of longer wavelengths also allows higher transmitted power levels whilst still remaining within eye safety limits. However, use of liquid crystals has the disadvantage that their optical state can only be switched relatively slowly (a few hundred times per second) compared with the switching speed of the SEED modulators.

<u>Alternative Embodiments</u>

In the above embodiments, a telecentric lens was used in combination with a reflective modulator to form a retro-reflector. Other types of retro-reflectors could be used. For example, as shown in Figures 14a and 14b a corner cube type retro-reflector 181 made from a glass prism could be used with a layer of electro-optic modulating material 183 on the outer surface 182 of the

corner cube 181. As shown, laser beams 185 and 187 from two different sources A and B respectively, pass through the modulating layer 183 and are modulated thereby in accordance with modulation data 14. The modulated laser beams 181 and 191 are then reflected off the walls of the corner cube 181 back to the respective sources A and B.

Alternatively, as shown in Figure 14c, a spherical retro-reflector 195 could be used with a layer of electro-optic modulating material 197 formed at the rear surface of the sphere 195. In operation, laser beams 199 and 201 from different sources (not shown) pass through the sphere 195 and are reflected and modulated with appropriate modulation data 14 by the modulating layer 197. The reflected beams 205, 207 then pass back through the sphere to the respective sources (not shown).

In the above embodiments, an array of SEED modulators or an array of liquid crystal modulators were used to modulate the laser beams from the different sources. Other types of modulators can be used, such as electro-optic modulators which can modulate the phase or the amplitude of the laser beams. For example, an electric field applied across Lithium Niobate (LiNbO3) produces a change in the refractive index of the crystal in the direction of the electric field. This in turn, imparts a corresponding phase change on the incident light. Commercially available phase modulators based on Lithium Niobate can operate with bandwidths up to several 100 MHz. However, a problem with providing an array of electro-optic modulators is that the current packaging used with these devices prevents them from being fused together to produce a single pixellated modulator which can be placed at the back focal plane of the telecentric lens system. However, this problem can be overcome by

using optical fibres with one end of the fibres being located at the back focal plane of the telecentric lens and with the other end interfaced with the appropriate individual modulator.

Another type of modulating device which can be used are micro-mechanical devices, such as the Texas Instruments micro-mirror array which is currently used in their projection display systems. Such devices are ideal for integration with the telecentric retro-reflector. However, as with the liquid crystal type modulators, the switching speed of the individual mirrors is relatively slow compared with the SEED modulators. In particular, the individual mirrors in current micro-mirror arrays can be switched at most at 500 times per second.

There are also a number of other micro-mechanical systems based on interferometry which offer high speed switching and the possibility of being built up into an integrated array to produce a pixellated modulator. For example, devices based on a Fabry-Perot cavity, fabricated by surface micro-machining, which use electrostatic actuation can achieve modulation rates of about 3 Mb/s. Figure 15a schematically illustrates the principal of operation of such a Fabry-Perot cavity type modulator. As shown, the modulator comprises a half mirror 216 and a plane mirror 215. The plane mirror 215 can be moved relative to the half mirror 216 between position A and position B by applying a suitable drive signal 217 which is generated by the piezo-electric drive circuit 219.

In operation, the laser beam 221 strikes the half mirror 216 and is partially reflected thereby. However, half of the laser beam passes through and is reflected by the plane mirror 215. When the plane mirror 215 is in

position A, the separation between the half mirror 216 and the plane mirror 215 is arranged to be half the wavelength (λ) of the laser beam 221 and when the mirror is in position B, the separation between the half mirror 216 and the plane mirror 216 is arranged to be a quarter of the wavelength (λ) of the laser beam 221. Therefore, when the plane mirror 215 is in position A, the portion of the laser beam which passes through the half mirror 216 travels one wavelength of the laser beam further than the portion of the laser beam which is reflected by the half mirror 216. Whereas, when the plane mirror 215 is in position B, the portion of the laser beam which passes through the half mirror 216 travels half the wavelength of the laser beam further than the portion of the laser beam which is reflected by the half mirror 216.

Figure 15b is a signal diagram which shows the electric field E_1 of the laser beam reflected from the half mirror 216, the electric field E_2 of the laser beam which is reflected by the plane mirror 215 and the electric field E_3 of the resulting reflected laser beam obtained by adding the two reflected laser beams E_1 and E_2, when the plane mirror 215 is in position A. As shown in Figure 15b, the two electric fields E_1 and E_2 are in-phase with each other and therefore, add together constructively to provide an electric field E_3 having a peak amplitude which is twice that of the electric fields E_1 and E_2. Figure 15c is a signal diagram which shows the electric fields E_1 and E_2 of the two reflected laser beams and of the resulting laser beam when the plane mirror 215 is in position B. As shown, the electric field E_2 of the laser beam reflected from the plane mirror 215 is 180° out of phase with the electric field E_1 of the laser beam reflected by the half mirror 216. Consequently, the two

electric fields E_1 and E_2 add destructively, resulting in the two reflected laser beams cancelling each other out.

Consequently, by generating appropriate drive signals 217, the piezo-electric drive circuit 219 can amplitude modulate the laser beam 221 in dependence upon the modulation data 14 which is received from the communications control unit 11.

In the above embodiments, the modulators were used, in effect, to amplitude modulate the laser beam transmitted from the user terminals. Other types of modulation can be performed on the laser beams. For example, as mentioned above, electro-optic modulators such as Lithium Niobate can apply a phase or an amplitude modulation to the laser beam. Modulation of the phase has the advantage that the phase of the reflected light does not change during transmission back to the user terminals. Therefore, phase modulation could be used to facilitate the transmission of multivalued data, which would significantly increase the data rate between the distribution nodes and the user terminals.

Alternatively, phase and frequency modulation can simply be achieved by moving a plane mirror 215 along the optical axis of the received laser beams. Such a modulator is illustrated in Figure 16a. In operation, the plane mirror 215 is moved between position A and position B by an electrostatic drive signal 217 generated by a piezo-electric drive circuit 219 in response to the modulation data 14.

By making the distance between position A and position B equal to a quarter of the wavelength (λ) of the laser

beam 221 and by stepping the position of the mirror 215 between position A and position B, a phase shift of 90° can be imparted on the reflected laser beam 221 because of the different path lengths over which the laser beam travels. Additionally, since frequency modulation is simply the time derivative of phase modulation, frequency modulation can be achieved by continuously ramping the phase, ie by continuously moving the mirror 215 between position A and position B, with the speed at which the mirror is moved between the two positions being determined by the number of consecutive like bits in the modulation data 14.

Figure 16b, illustrates the way in which the mirror 215 should be moved to achieve phase and frequency modulation for the modulation data 14 shown in the top diagram of Figure 16b. In particular, the middle diagram of Figure 16b, shows phase modulation, wherein the position of the mirror 215 is stepped between position B and position A in dependence upon the modulation data 14. As shown in the bottom signal diagram of Figure 16b, frequency modulation can be achieved by continuously ramping the position of the mirror between position A and position B in dependence upon the modulation data 14.

Another type of light modulator which can be used is being developed by Silicon Light Machines in California and is an interferometric micro-machined technology which is based on an electrostatically actuated diffraction grating. With this technology, single pixel switching speeds of the order of 20 ns can be achieved. Silicon Light Machines are currently producing a linear array of devices for display applications, and they are developing a two-dimensional array. Such modulators would be highly suited for some applications since these

devices can be fabricated using standard lithographic techniques at relatively low cost in volume.

In the above embodiments, a 50mW laser diode was provided in each of the user terminals, so that the user terminals can communicate with the corresponding local distribution node within a range of about 150 metres. In applications where the distance between the user terminals and the local distribution nodes is relatively small, such as a few metres, lower powered laser diodes such as those which are commonly used in CD players or light emitting diodes could be used. Alternatively, in other applications, such as satellite to satellite communications, high powered lasers could be used where the distance between the signalling devices is relatively large.

In the above described embodiments, a pixellated modulator, ie an array of modulators, was employed to modulate the light from the different sources. In an alternative embodiment, a single modulator which covers the entire back focal plane of the telecentric lens could be used. In such an embodiment, each of the users would receive either the same information or different channels could be provided for the respective users by time division multiplexing the modulation which is applied to the single modulator. In such an embodiment, each of the sources would receive all the modulated data but each source would only demodulate the data which is directed to it. However, this type of single modulator is not preferred because the modulator must be relatively large and large modulators are difficult to produce and, for some applications, cannot be modulated quickly enough to provide the desired data rate.

In the above embodiments, when the reflected light hits the beam splitter, some of the reflected light will propagate through towards the laser diode. In order to increase the amount of light which is reflected towards the photo-diode, a polarised beam splitter and a quarter wave plate could be used in the user terminal. In operation, the polarisation of the laser beam output from the laser diode would have to be aligned with the polarisation of the polarised beam splitter so that the output laser beam passes through the beam splitter, the quarter wave plate and the optical beam expander to the retro-reflector and modem unit. The quarter wave plate converts the linearly polarised light beam into, for example, right hand circular polarised light. The mirror/modulator in the retro-reflector then changes the polarised light of the reflected beam into left hand circular polarisation which is then converted back into linearly polarised light by the quarter wave plate. However, due to the change from right hand circular to left hand circular, the linear polarisation of the reflected beam after the quarter wave plate is orthogonal to the original polarisation of the laser beam. Therefore, when the reflected beam reaches the polarised beam splitter, all of it is deflected towards the photo-diode.

In the above embodiments, the receiver circuitry of the user terminals was arranged to directly detect the modulation data applied to the reflected beam. However, since the receiver circuit and the optical source are located at the same point in the communication system, coherent homodyne optical detection can be used which improves the receiver sensitivity over conventional direct detection techniques at little additional complexity and cost. In particular, by arranging for

some of the laser beam from the laser diode to be split from the main path onto the photo diode together with the reflected beam, the modulation data is retrieved by coherent homodyne detection with a sensitivity gain of the order of 10dB over the direct detection technique.

In the above embodiments where a two-way signalling system was provided between the local distribution node and the user terminals, a combined array of modulators and demodulators was provided in the retro-reflector and modem unit. Alternatively, as shown in Figure 17, the array of modulators 235 can be provided separately from the array of demodulators 237, by placing a beam splitter 239 between the telecentric lens 51 and the array of modulators 235. Additionally, as represented by the dashed line 241, a lens may also be provided between the beam splitter 239 and the array of photo detectors 237 if the two arrays have a different size.

In the above embodiments which use a telecentric lens, the laser beams from the different sources are focused onto the array of modulators which are placed at or near the focal plane of the telecentric lens. However, the convergence angle of the laser beam onto the respective modulator depends upon the particular optics used in the telecentric lens. Where this angle of convergence is relatively large, the collimation of the rays entering the modulator can be improved by placing a micro lens in front of each of the modulators which introduces negative optical power. Figure 18, schematically shows the way in which a micro lens 251 can be placed in front of a modulator element m_{ij} which has the effect of collimating the rays 253 and 255 into the modulator m_{ij}.

In the above embodiments, a planar array of modulators

was used within the local distribution nodes. However, by choosing appropriate focusing elements in the telecentric lens, a curved or plane and partially curved array of modulators could be used with the curvature of the modulator array being designed so that the principal rays through the telecentric lens are normal to the surface of the respective modulators. Similarly, where a transmissive type modulator is used, the plane mirror located at the focal plane of the telecentric lens could also be curved depending on the optics which are used.

In the above embodiments, a reflective surface was used either in the modulator or after the modulator for reflecting the laser beams back to the respective sources. Ideally, a phase conjugate mirror would be used since this allow distortions in the laser beam transmission to be compensated which further reduces the transmission loss.

In the above embodiments, the signals used to communicate information were optical signals. However, other frequencies could be used. For example, if microwave frequencies are used, an array of microwave waveguides could be placed at the focal plane of a telecentric microwave lens, with the modulation being achieved by varying the impedance matching of the waveguide.

In the above embodiments, the point to multipoint signalling system comprised a three-layer hierarchy. The present invention is not intended to be so limited. The signalling system used could be between a single data distribution system and a plurality of separate destination terminals. Alternatively still, the central distribution system could form part of a larger communication system with higher levels of hierarchy.

In the above embodiments, a point to multipoint signalling system has been described. Figure 19 shows a multipoint to point signalling system for communicating data from different sources to a central monitoring system 261. As shown, the central monitoring system 261 is connected to a plurality of local monitoring nodes 263 via optical fibre bundles 5. In turn, the local monitoring nodes 263 receive communications through free space which are transmitted by sensor terminals 267 which are fixed relative to the monitoring nodes 263.

In operation, the sensor terminals 267 monitor some physical event, and transmit optical status data to the local monitoring node 263 in response. The local monitoring nodes 263 then collate the data and transmit appropriate data back to the central monitoring system 261 via the optical fibre bundles 5. In the embodiment, the sensor terminals 267 sense motion, temperature, humidity, sound etc and form part of a security system.

Figure 20, schematically illustrates in more detail, the main components of the local monitoring node 263 and some of the sensor terminals 267. As shown, each sensor terminal 267 comprises a controller 271 which is operable to receive signals from one or more sensors 273 and to output modulation data in dependence thereon for modulating the light output by a light source 279.

As shown, the local monitoring node 263 comprises a video camera 283 for monitoring the light output from the respective sensor terminals 267, and to output appropriate video signals 285 to a signal detector 287. In operation, the sensors 273 sense the local temperature/movement etc and supply corresponding sensor

signals to the controller unit 271 of the respective sensor terminal 267. The controller unit 271 analyses the sensor data and, if appropriate, generates modulation data 275 for modulating the light 277 produced by the corresponding light source 279. In response, the output video signal 285 from the video camera 283 changes, due to the modulation of the light source 279 and this change is detected by the signal detector 287. The signal detector 287 can identify from which sensor terminal 267 the modulated light came from simply by determining the location of the modulated light within one frame of the video signal 285, because the sensor terminals 267 are fixed relative to the local monitoring node 263.

In its simplest form, the modulation performed to the light 277 will simply be to switch on the light source 279 in response to a particular event sensed by the corresponding sensor or sensors 273. Alternatively, the light 277 might be modulated to include data describing the event which has been sensed by the sensor 273.

Instead of using a video camera 283, a telecentric lens could be used with an array of photo detectors placed at the focal plane of the telecentric lens, with each detector element of the array being associated with a predetermined sensor terminal 267. However, such a system is equivalent to the video camera, where the array of detectors comprises an array of charged coupled devices, with a respective charge coupled device being assigned to a corresponding sensor terminal 267.

The monitoring system described above has many applications. For example, it can be used in security applications for monitoring a number of different warehouses and for relaying the sensed data back to a

central security station. Alternatively, the system could be employed in industrial applications where the sensed conditions are used to control the industrial plant. In particular, in such a system, each of the sensor terminals 267 might have a corresponding actuation terminal which is controlled by sending appropriate control data from the central monitoring system back through the optical fibre bundles 5 to the local monitoring nodes 263 and back to the corresponding actuation terminals associated with the sensor terminal.

The present invention is not limited by the exemplary embodiments described above, and various other modifications and embodiments will be apparent to those skilled in the art.

Claims:

1. A point to multipoint signalling system, comprising a first signalling device and a plurality of second signalling devices, wherein:

the first signalling device comprises: means for receiving signals transmitted from the plurality of second signalling devices; means for modulating the received signals with respective modulation data for the second signalling devices; and means for reflecting the modulated signals back to the respective second signalling devices; and wherein

each second signalling device comprises: means for generating a signal; means for transmitting the generated signal to said first signalling device; means for receiving the modulated signal which is reflected back from said first signalling device; and means for retrieving the modulation data from the reflected signal.

2. A system according to claim 1, wherein said receiving means comprises focusing means for focusing said received signals onto said reflecting means.

3. A system according to claim 2, wherein the focusing means comprises a telecentric lens and wherein the reflecting means is located substantially at the back focal plane of the telecentric lens.

4. A system according to claim 2 or 3, wherein the focusing means has a front and back focal plane, and wherein a stop member is located substantially at said front focal plane for blocking part of the received signals from said focusing member, and wherein said reflecting member is located substantially at said back focal plane.

5. A system according to claim 4, wherein said focusing means comprises a wide angled lens.

6. A system according to any of claims 2 to 5, wherein said modulating means is transmissive and is located between said focusing means and said reflecting means.

7. A system according to any preceding claim, wherein said reflecting means comprises a retro-reflector.

8. A system according to any preceding claim, wherein said reflecting means comprises a mirror.

9. A system according to claim 2 or any claim dependent thereon, wherein said reflecting means is curved or partially curved to match the focal plane of said focusing means.

10. A system according to any preceding claim, wherein said modulating means is operable to modulate at least one of the amplitude, phase, frequency or polarisation of the received signals.

11. A system according to any preceding claim, wherein said modulating means comprises said reflecting means.

12. A system according to any preceding claim, wherein said received signals comprise light.

13. A system according to claim 12, wherein said modulating means comprises a self electro-optic effect device.

14. A system according to claim 12, wherein said modulating means comprises an electro-optic modulator.

15. A system according to claim 12, wherein said modulating means comprises a liquid crystal modulator.

16. A system according to claim 12, wherein said modulating means comprises a micro-mechanical modulator.

17. A system according to any preceding claim, wherein said modulating means is operable to apply the same modulation data to the signal received from each second signalling device.

18. A system according to any preceding claim, wherein the same modulating means is used to modulate each of the received signals in a time multiplexed manner.

19. A system according to any of claims 1 to 17, wherein said modulating means comprises a plurality of modulators, at least one for each of said second signalling devices.

20. A system according to claim 19, wherein said plurality of modulators are arranged in a regular array.

21. A system according to claim 20, wherein said plurality of modulators are arranged in a two-dimensional array.

22. A system according to claim 20 or 21, further comprising an array of micro-lenses corresponding to said array of modulators, for increasing the collimation of the signals input to the respective modulators.

23. A system according to any preceding claim, wherein at least one of said second signalling devices is

operable to transmit a message to said first signalling device by modulating the transmitted signal, and wherein said first signalling device comprises means for retrieving the message from the received signal.

24. A system according to claim 23, wherein said at least one second signalling device is operable to apply a different modulation to said signal from the modulation applied by said first signalling device.

25. A system according to claim 23 or 24, wherein said first signalling device comprises a plurality of detectors for detecting the signal transmitted from each of said second signalling devices, and means for retrieving any messages modulated onto the received signals by the respective second signalling devices.

26. A system according to claim 25 when dependent upon claim 20 or 21, wherein said plurality of detectors are arranged in an array corresponding to the array of modulators.

27. A system according to claim 26, wherein the corresponding detector and modulator are located adjacent to each other.

28. A system according to claim 26, wherein the array of detectors and the array of modulators are located separately from each other, and wherein means is provided for reflecting part of the received signals onto the respective modulator/demodulator arrays.

29. A system according to claim 12 or any claim dependent thereon, wherein each of said second signalling devices comprises a laser, a laser diode or a light

emitting diode.

30. A system according to claim 12 or any claim dependent thereon, wherein each of said second signalling devices comprises a laser diode which is operable to output laser light of a predetermined wavelength, and wherein each of said second signalling devices further comprises means for collimating the laser beam output by said laser diode.

31. A signalling device comprising means for receiving signals transmitted from a plurality of sources; means for modulating the received signals with respective modulation data for the sources; and means for reflecting the modulated signals back to the respective sources.

32. A signalling device comprising the technical first signalling device features of any of claims 1 to 30.

33. A signalling kit comprising one or more signalling devices according to claim 31 or 32 and a plurality of second signalling devices, each comprising: means for generating a signal; means for transmitting the generated signal to the first signalling device; means for receiving the modulated signal which is reflected back from the first signalling device; and means for retrieving the modulation data from the reflected signal.

34. A point to multipoint signalling method using a first signalling device and a plurality of second signalling devices, the method comprising the steps of:

at the first signalling device: receiving signals transmitted from the plurality of second signalling devices; modulating the received signals with respective modulation data for the second signalling devices; and

reflecting the modulated signals back to the respective second signalling devices; and

at each of said second signalling devices: generating a signal; transmitting the generated signal to the first signalling device; receiving the modulated signal which is reflected back from said first signalling device; and retrieving the modulation data from the reflected signal.

35. A retro-reflector comprising:

a focusing member, having first and second focal planes, for focusing signals received from a source;

a stop member, located substantially at said first focal plane, for blocking part of the signal from said focusing member; and

means, located substantially at said second focal plane, for reflecting said received signals back to said source.

36. A retro-reflector according to claim 35, further comprising a wide angled lens located in front of said stop member.

37. A retro-reflector according to claim 35 or 36 wherein said reflecting means has a curved or partially curved surface to match the second focal plane of said focusing member.

38. A retro-reflector according to any of claims 35 to 37, wherein said reflecting means comprises a mirror.

39. A retro-reflector according to any of claims 35 to 38, further comprising a modulator for modulating the received signals with modulation data.

40. A retro-reflector according to claim 39, wherein said modulator is transmissive and is located between said focusing member and said reflecting member.

41. A retro-reflector according to claim 39 or 40, wherein said modulating means is operable to modulate at least one of the amplitude, phase, frequency or polarisation of the received signals.

42. A retro-reflector according to claim 39, wherein said modulator comprises said reflecting means.

43. A retro-reflector according to any of claims 35 to 42, wherein said received signals comprise light.

44. A retro-reflector according to claim 41, wherein said modulating means comprises a self electro-optic effect device.

45. A retro-reflector according to any of claims 39 to 43, wherein said modulator comprises an electro-optic modulator.

46. A retro-modulator according to any of claims 39 to 43, wherein said modulator comprises a liquid crystal modulator.

47. A retro-reflector according to any of claims 39 to 43, wherein said modulator comprises a micro-mechanical modulator.

48. A retro-reflector according to any of claims 39 to 47 operable to receive signals from a plurality of sources, and wherein said modulator is operable to apply the same modulation data to the signals received from

each of said sources.

49. A retro-reflector according to claim 48, wherein the same modulator is used to modulate each of the received signals in a time multiplexed manner.

50. A retro-reflector according to claim 48 or 49, wherein said modulator comprises a plurality of modulators each arranged to modulate the signals received from a respective one of said sources.

51. A retro-reflector according to claim 50, wherein said plurality of modulators are arranged in a regular array.

52. A retro-reflector according to claim 51, wherein said plurality modulators are arranged in a two-dimensional array.

53. A retro-reflector according to any claim 51 or 52, further comprising an array of micro-lenses corresponding to said array of modulators, for increasing the collimation of the signals input to the respective modulators.

54. A retro-reflector according to any of claims 35 to 53, further comprising a detector for detecting the received signal and means for retrieving any message carried by the received signal.

55. A retro-reflector according to any of claims 35 to 54, further comprising a plurality detectors for detecting the signal received from a plurality of different sources and means for retrieving any messages modulated onto the received signals by the respective

sources.

56. A retro-reflector according to claim 55 when dependent upon claim 51 or 52, wherein said plurality of detectors are arranged in an array corresponding to the array of modulators.

57. A retro-reflector according to claim 56, wherein the corresponding detector and modulator are located adjacent to each other.

58. A retro-reflector according to claim 56, wherein the array of detectors and the array of modulators are located separately from each other, and wherein means is provided from reflecting part of the received signals onto the respective modulator/demodulator arrays.

59. A retro-reflector comprising a telecentric lens for receiving and focusing light from a light source and a reflecting means located substantially at the focal plane of said telecentric lens for reflecting said light back to said light source.

60. A multipoint to point signalling system, comprising a first signalling device and a plurality of second signalling devices located at preselected locations with respect to said first signalling device, wherein:

said first signalling device comprises: a plurality of light detectors for detecting light transmitted from the plurality of second signalling devices; and means for focusing the light transmitted from each second signalling device onto a respective light detector; and wherein

each second signalling device comprises: at least one sensor input terminal operable to receive a signal

from a sensor; and a light source operable to generate a light beam in dependence upon said sensor signal for transmission to said first signalling device.

61. A system according to claim 60, wherein said first signalling device comprises a camera and means for detecting the transmitted light from the plurality of second signalling devices from the signal output by said camera.

62. A system according to claim 60 or 61, wherein each second signalling device comprises a controller for monitoring the received sensor signals and for modulating the light beam output from said light source in dependence thereon.

63. A system according to claim 62, wherein said controller is operable to switch said light source on upon detection of a predetermined sensor signal.

64. A system according to claim 60, wherein said first signalling device comprises a telecentric lens.

65. A system according to claim 60, wherein said plurality of light detectors are arranged in an array.

66. A system according to claim 65, wherein said array is a two-dimensional array.

67. A multipoint to point signalling method using a first signalling device and a plurality of second signalling devices located at pre-selected locations with respect to said first signalling device, the method comprising the steps of:

at said first signalling device: using a plurality

of light detectors for detecting light transmitted from the plurality of second signalling devices and focusing the light transmitted from each second signalling device onto a respective light detector; and

at each second signalling device: receiving a signal from a sensor and generating a light beam in dependence upon the received sensor signal for transmission to said first signalling device.

68. An optical point to multipoint signalling system comprising a first signalling device and a plurality of second signalling devices, wherein:

the first signalling device comprises a retro-reflector operable to receive light beams from the plurality of second signalling devices and to reflect the received light beams back to the respective second signalling devices; and means for modulating the received light beams with respective modulation data for the second signalling devices; and

wherein each second signalling device comprises a light source for outputting a light beam towards said first signalling device; and means for receiving the modulated light beam which is reflected back from said first signalling device.

69. A data distribution system comprising one or more point to multipoint signalling systems according to any of claims 1 to 30 or 68 and/or a retro-reflector according to any of claims 35 to 59.

70. An office communications network comprising one or more point to multipoint signalling systems according to any of claims 1 to 30 or 68 and/or a retro-reflector according to any of claims 35 to 59.

71. A transmitter circuit comprising a retro-reflecting element arranged to receive signals from a plurality of different sources and to reflect the signals back to the respective sources and whose properties can be modified so that a characteristic of the retro-reflected signals can be modulated with information.

72. A signalling device comprising means for receiving signals transmitted from a plurality of sources; a plurality of modulators each for modulating signals from a respective source; and means for reflecting the modulated signals back to the plurality of sources.

73. A signalling system comprising a central distribution system for transmitting information to a plurality of first signalling devices, each first signalling device comprising means for receiving signals transmitted from a plurality of sources, means for modulating the received signals in dependence upon information received from said central distribution system; and means for reflecting the modulated signals back to the respective sources.

74. A signalling system comprising: a first signalling device, a plurality of second signalling devices and a plurality of third signalling devices, wherein:

the first signalling device comprises means for transmitting signals to each of said second signalling devices;

wherein each of said second signalling devices comprises means for receiving signals transmitted from a plurality of third signalling devices; means for generating modulation data in dependence upon the signals received from said first signalling device; means for modulating the signals received from said plurality of

third signalling devices with respective modulation data for the third signalling devices; and means for reflecting the modulated signals back to the respective third signalling devices; and

wherein each third signalling device comprises means for generating a signal; means for transmitting the generated signal to said second signalling device; and means for receiving the modulated signal which is reflected back from said second signalling device.

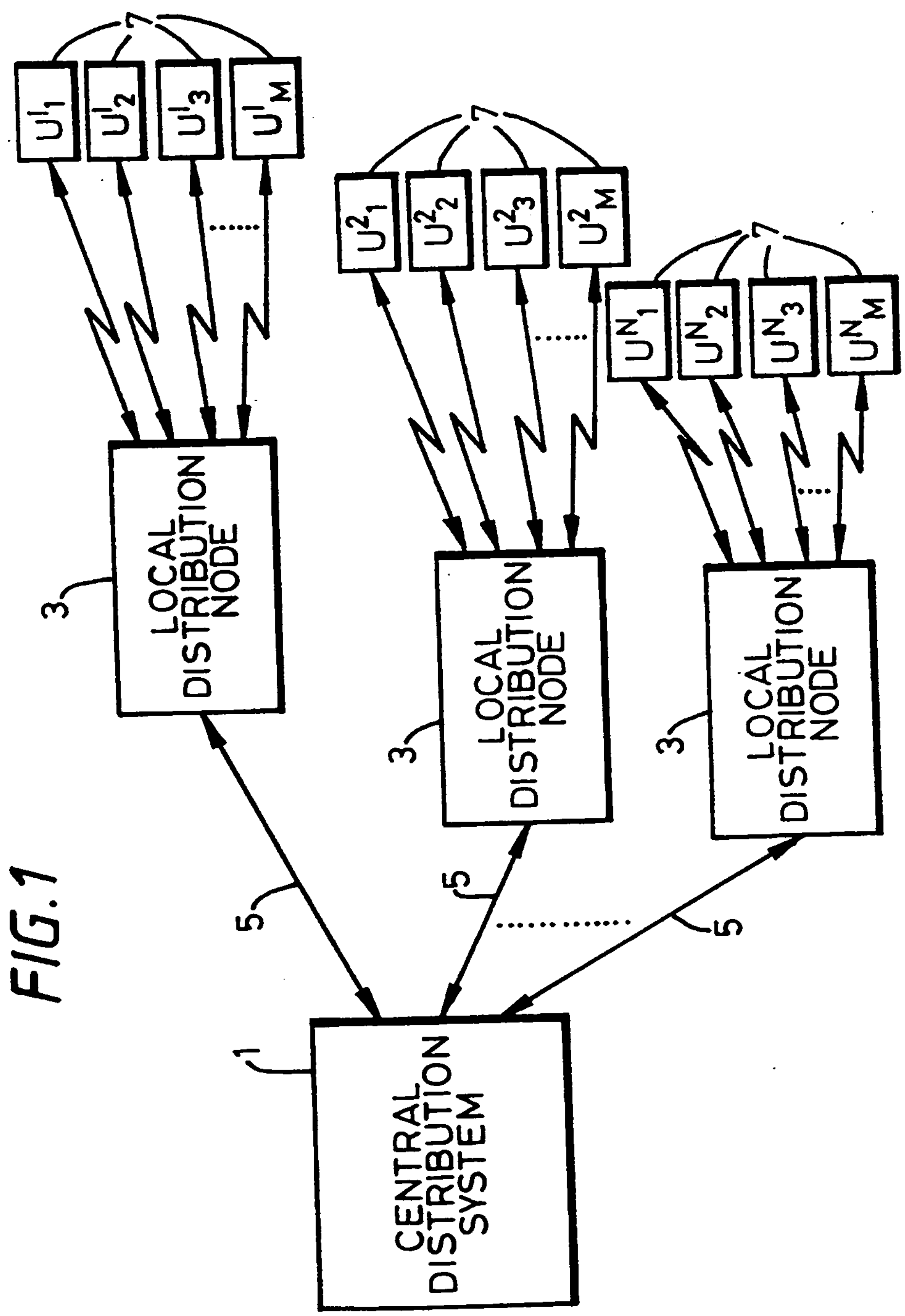

CENTRAL DISTRIBUTION SYSTEM
LOCAL DISTRIBUTION NODE
LOCAL DISTRIBUTION NODE
LOCAL DISTRIBUTION NODE
1
3
5
7

FIG.1

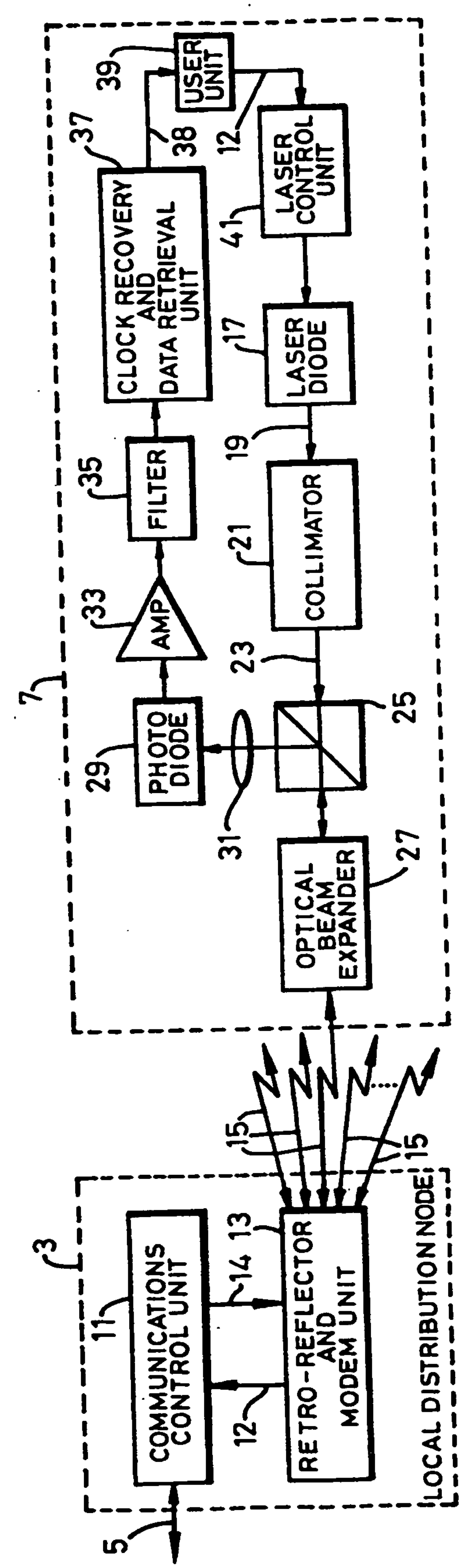

USER UNIT
LASER CONTROL UNIT
CLOCK RECOVERY AND DATA RETRIEVAL UNIT
LASER DIODE
FILTER
COLLIMATOR
AMP
PHOTO DIODE
OPTICAL BEAM EXPANDER
COMMUNICATIONS CONTROL UNIT
RETRO-REFLECTOR AND MODEM UNIT
LOCAL DISTRIBUTION NODE
39
37
38
12
41
17
19
35
21
33
23
7
25
29
31
27
15
15
3
11
14
13
12
5

FIG. 2

FIG. 3

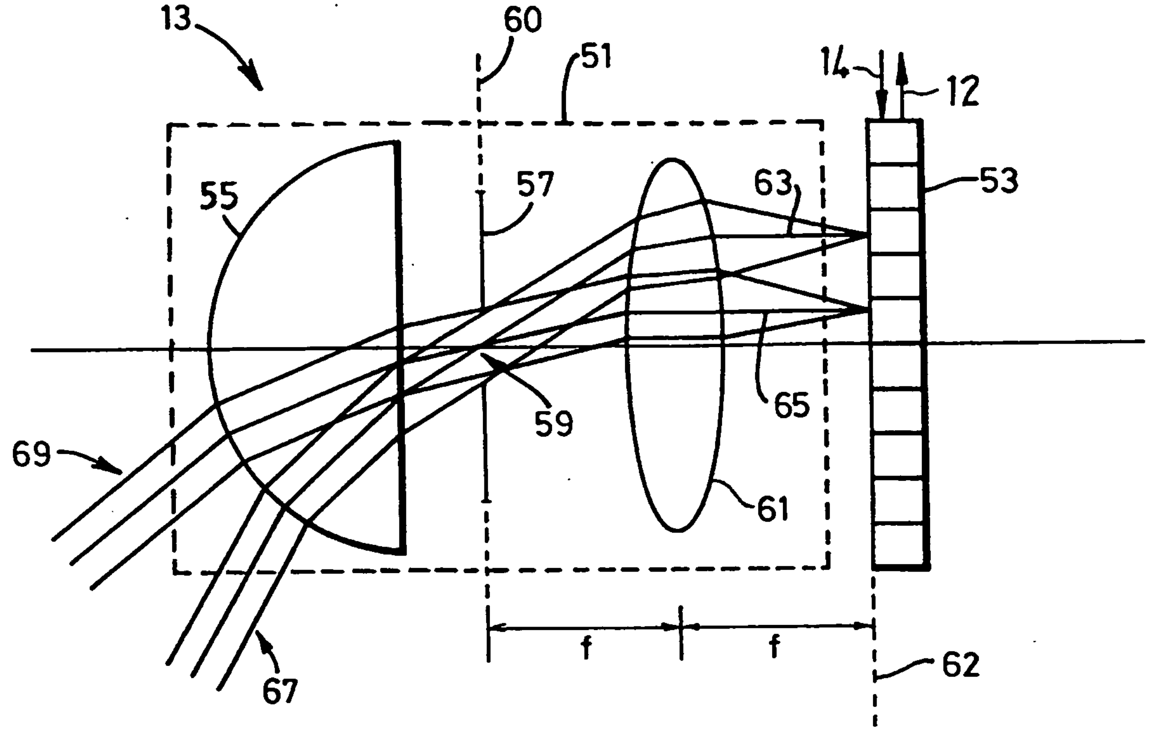
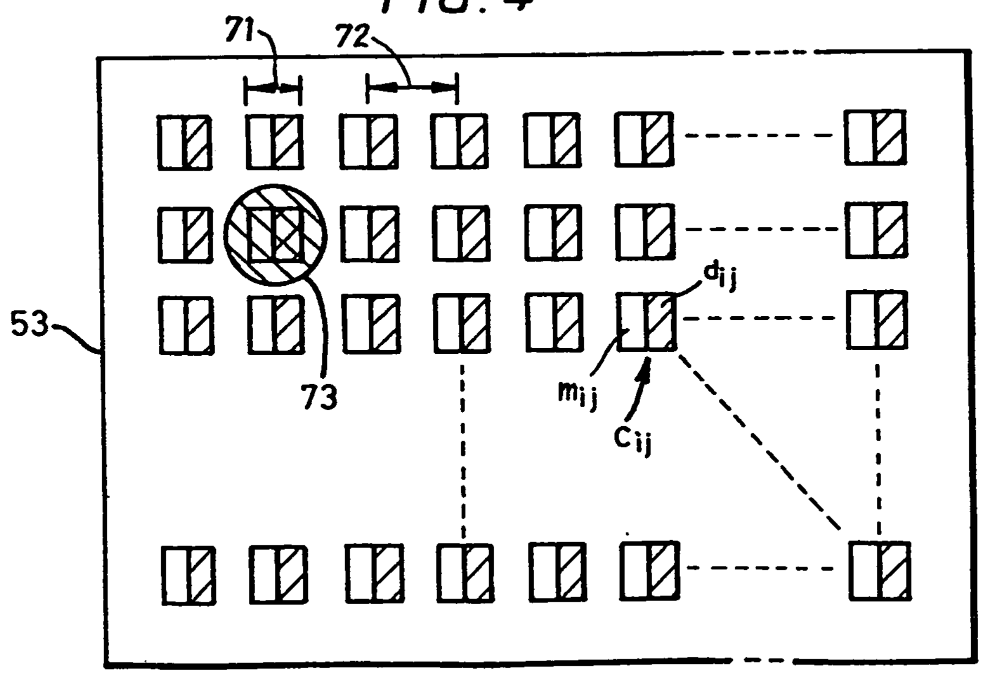


FIG. 4



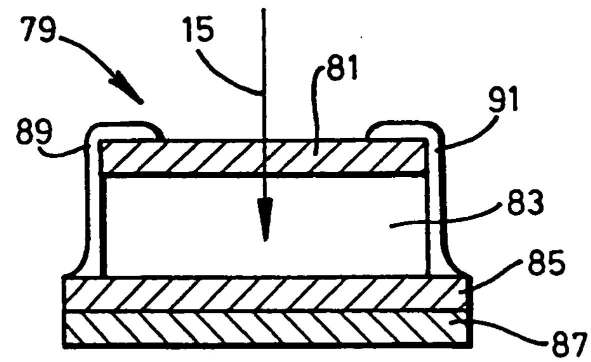


FIG. 5a

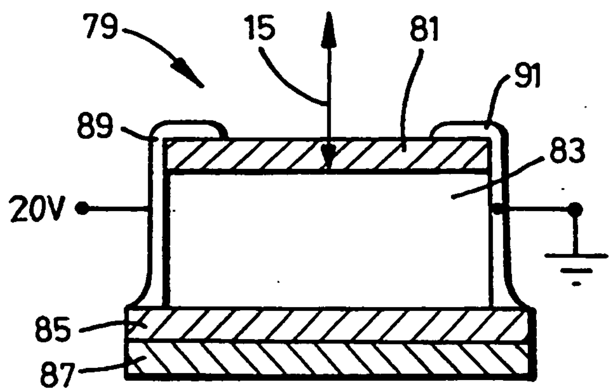
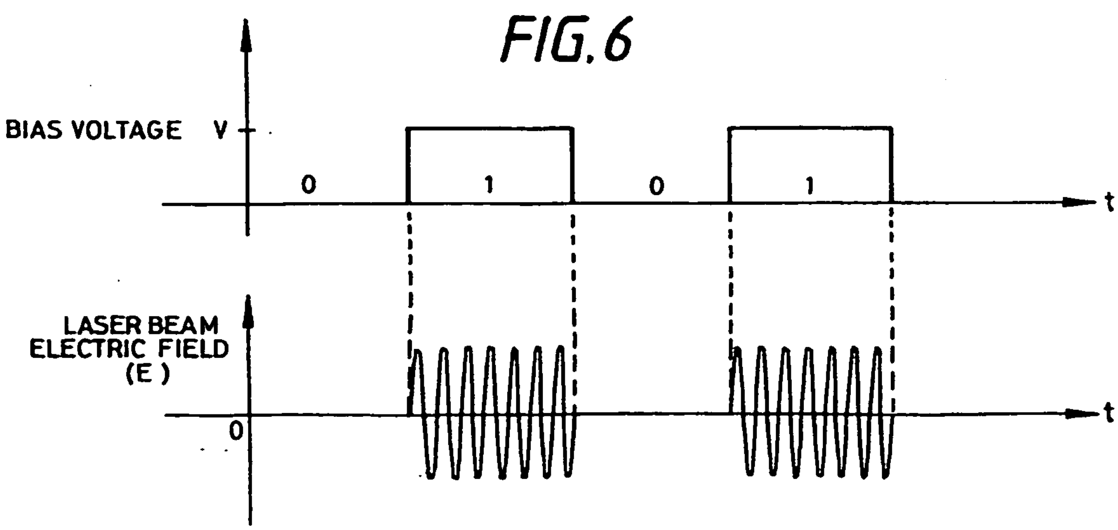


FIG. 5b

FIG. 6



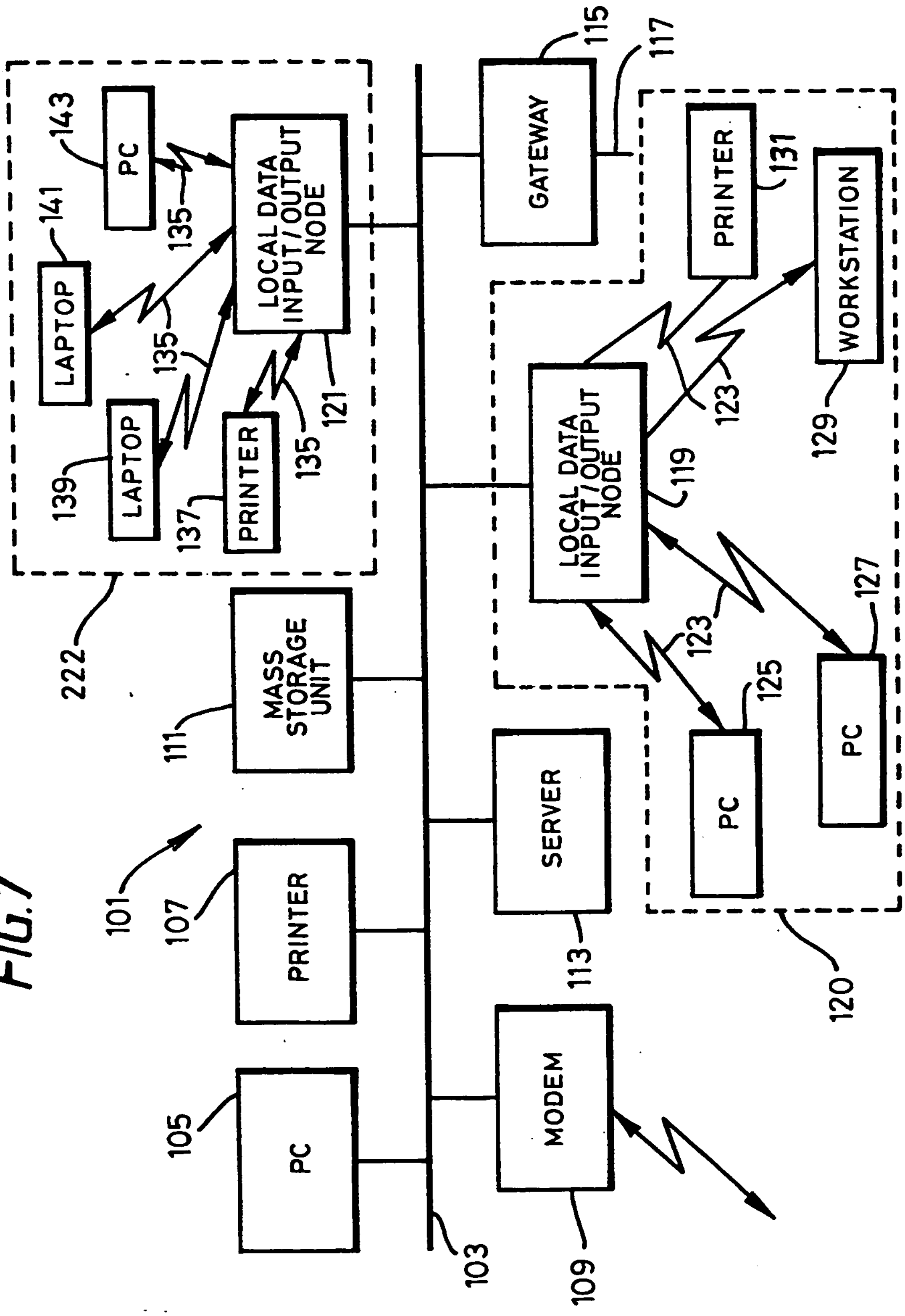

PC
143
LOCAL DATA INPUT/OUTPUT NODE
135
141
LAPTOP
135
LAPTOP
139
PRINTER
137
135
121
222
MASS STORAGE UNIT
111
101
PRINTER
107
PC
105
103
GATEWAY
115
117
PRINTER
131
WORKSTATION
129
123
LOCAL DATA INPUT/OUTPUT NODE
119
123
127
PC
125
PC
SERVER
113
120
MODEM
109

FIG.7

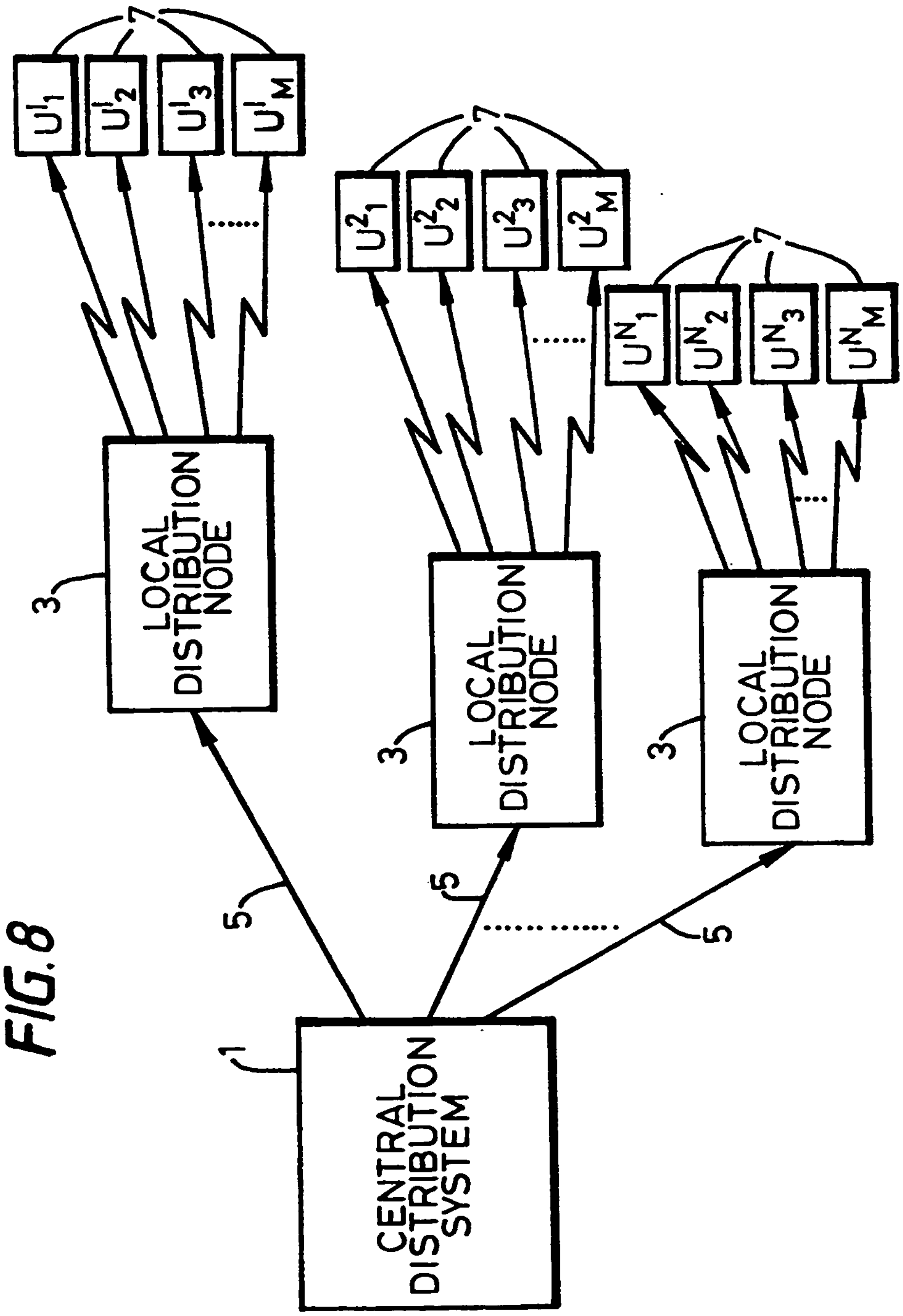

CENTRAL DISTRIBUTION SYSTEM
1
5
5
5
3
LOCAL DISTRIBUTION NODE
3
LOCAL DISTRIBUTION NODE
3
LOCAL DISTRIBUTION NODE
7
7
7
U^1_1
U^1_2
U^1_3
U^1_M
U^2_1
U^2_2
U^2_3
U^2_M
U^N_1
U^N_2
U^N_3
U^N_M

FIG.8

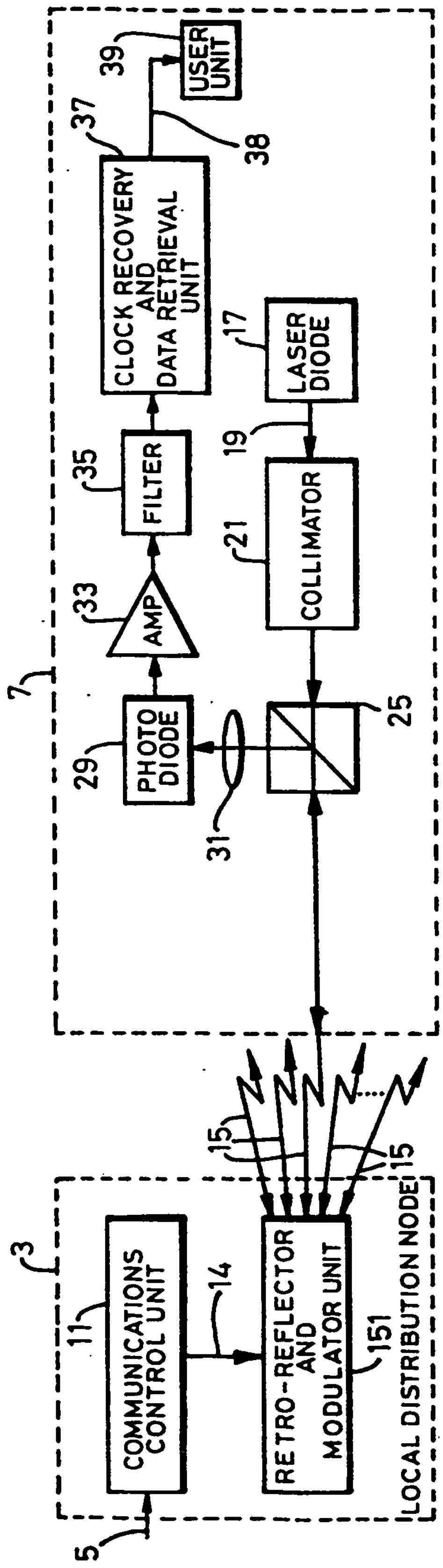

USER UNIT
39
37
38
CLOCK RECOVERY AND DATA RETRIEVAL UNIT
LASER DIODE
17
FILTER
35
19
COLLIMATOR
21
AMP
33
7
PHOTO DIODE
29
25
31
15
15
COMMUNICATIONS CONTROL UNIT
11
3
14
RETRO-REFLECTOR AND MODULATOR UNIT
151
LOCAL DISTRIBUTION NODE
5

FIG. 9

FIG. 10

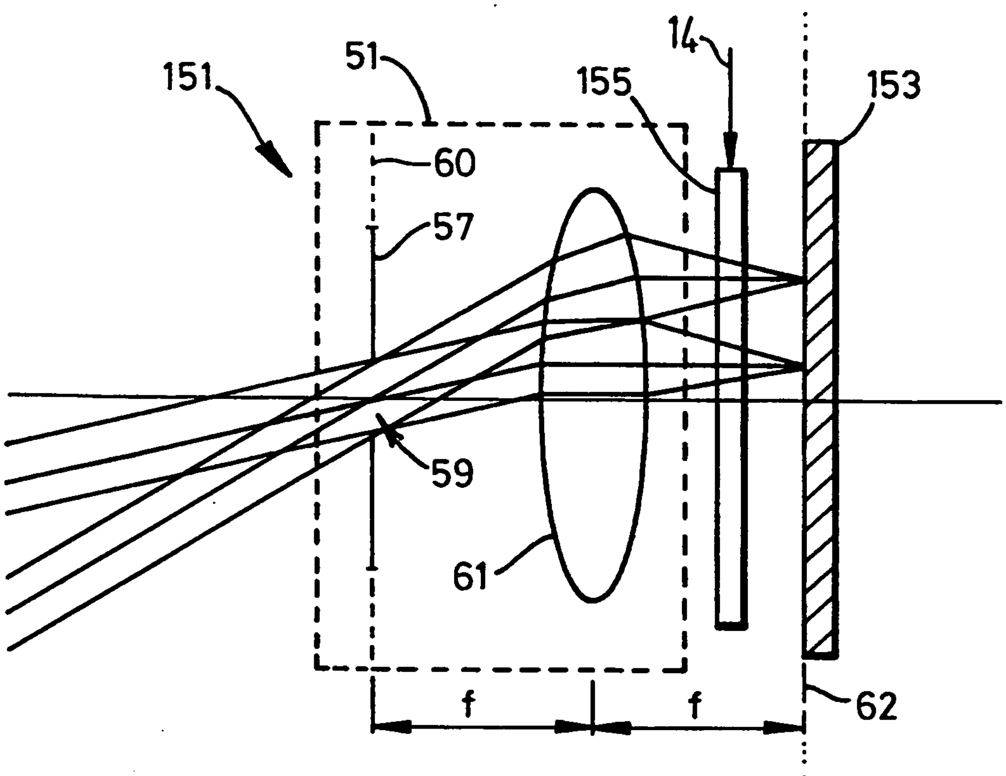
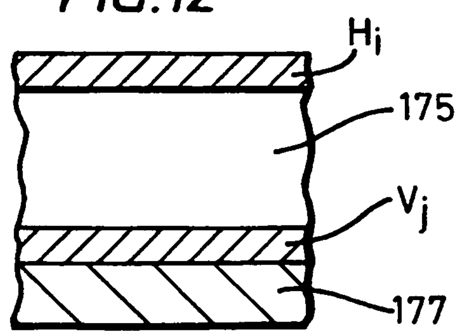


FIG. 12



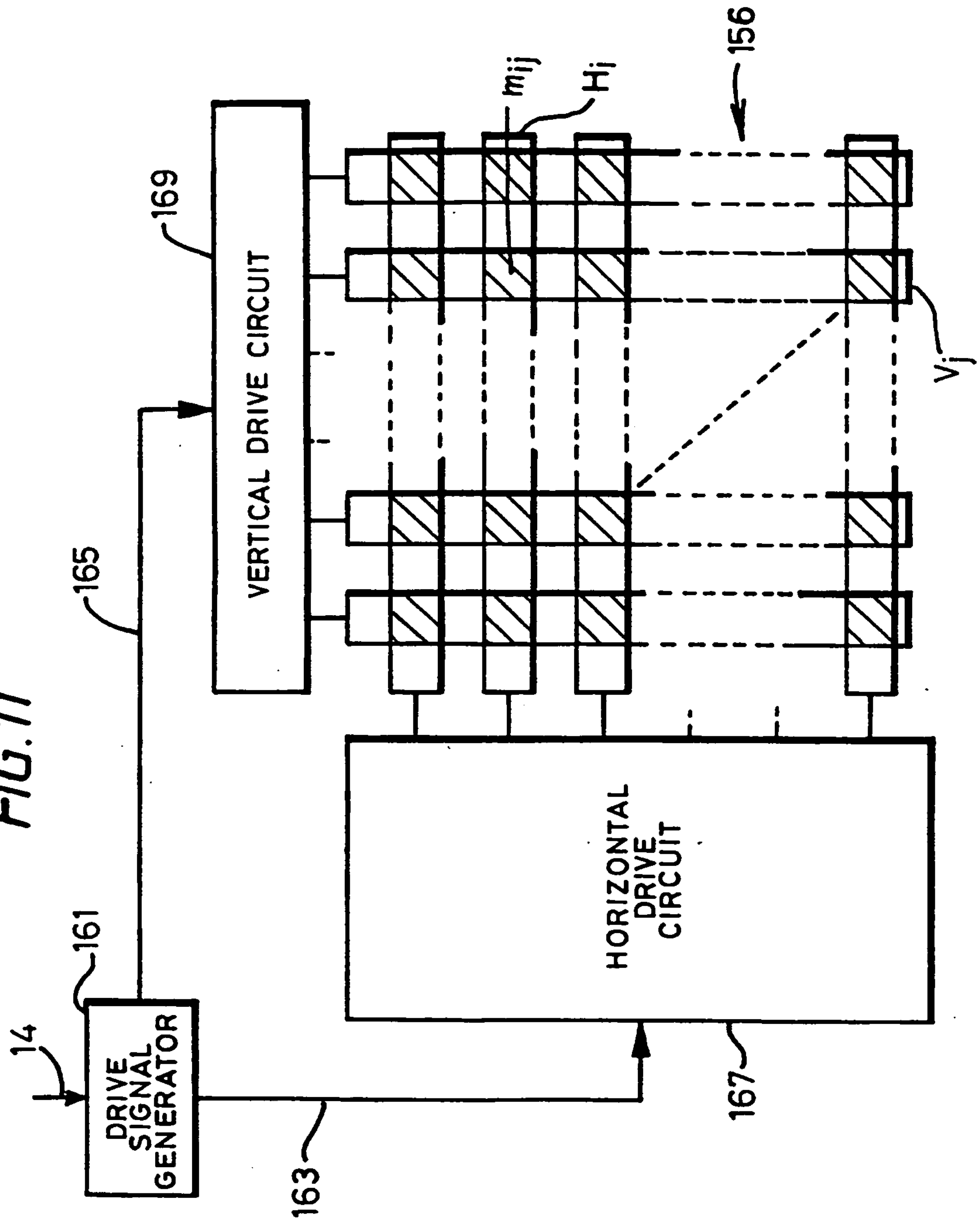

14
DRIVE SIGNAL GENERATOR
161
163
165
VERTICAL DRIVE CIRCUIT
169
HORIZONTAL DRIVE CIRCUIT
167
m_{ij}
H_i
V_j
156

FIG.11

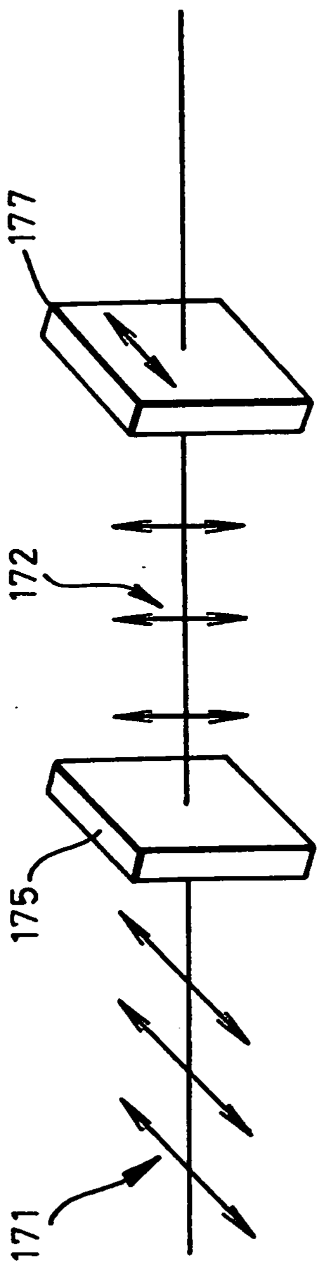


FIG. 13a

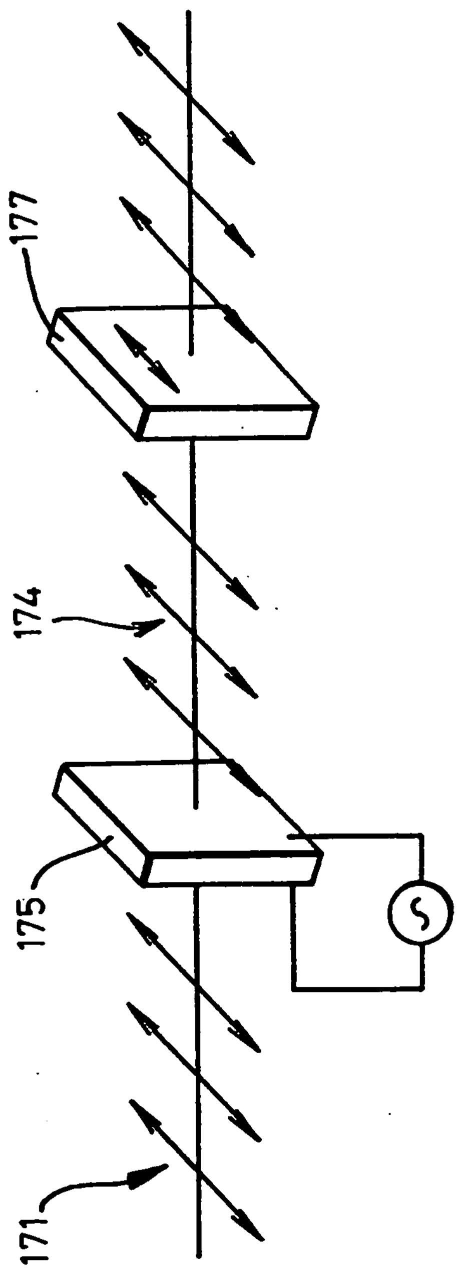
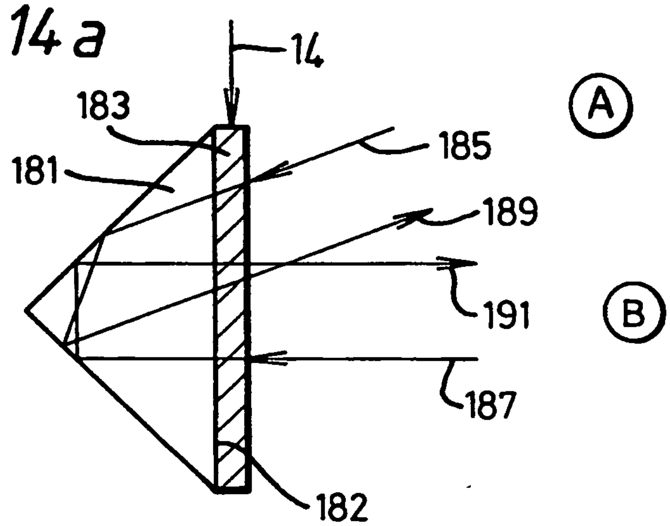


FIG. 13b

FIG. 14a



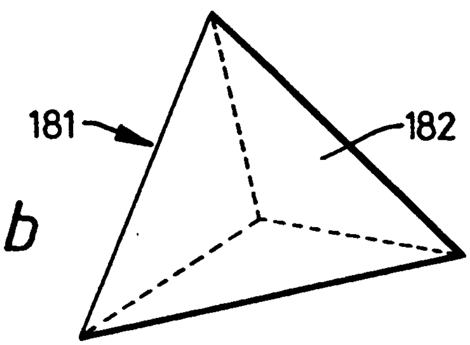


FIG. 14b

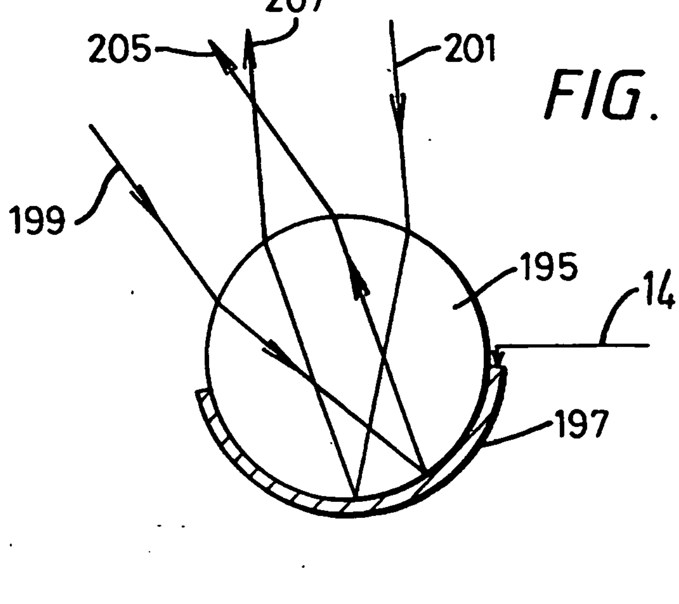


FIG. 14c

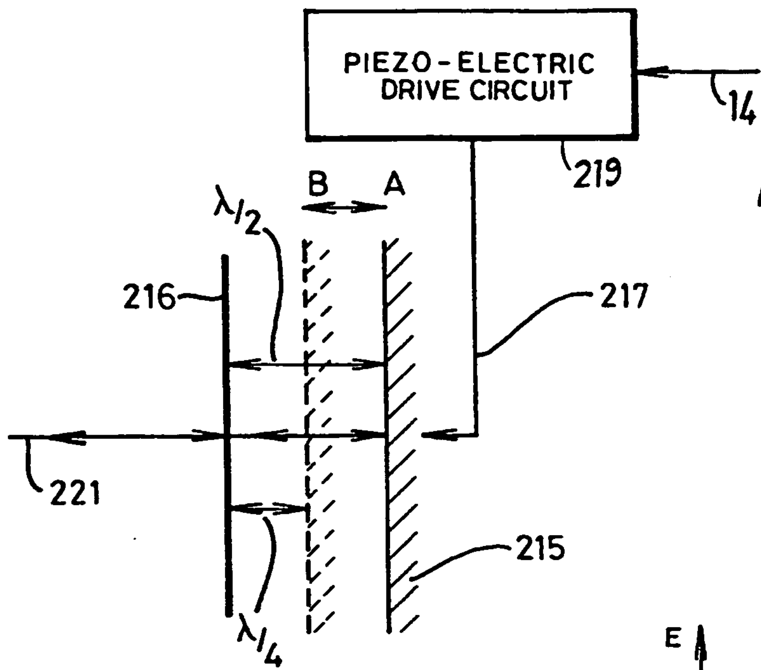


FIG. 15a

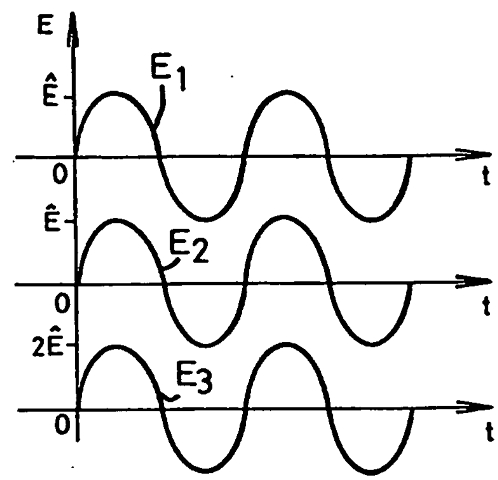


FIG. 15b

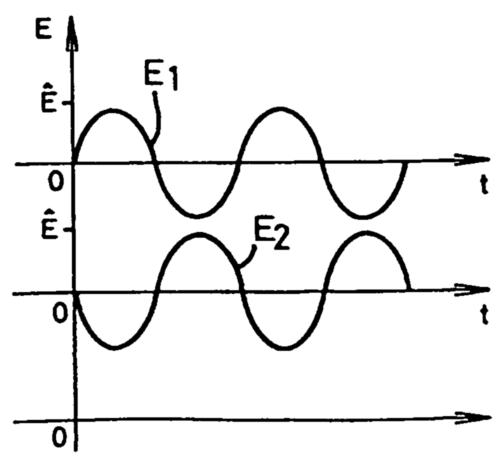


FIG. 15c

FIG. 16a

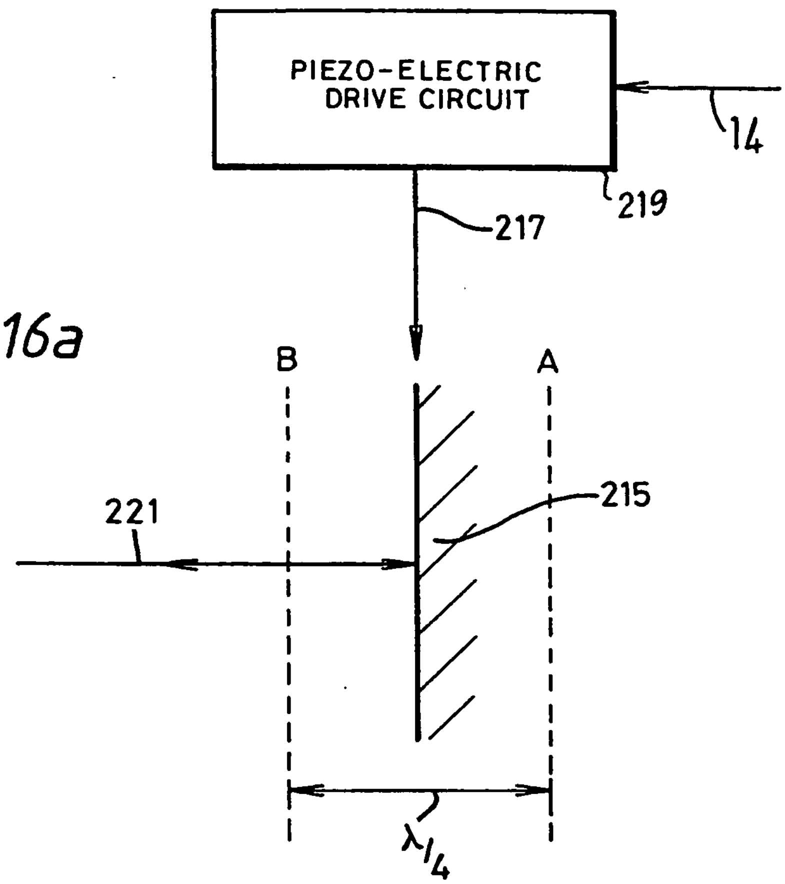


FIG. 16b

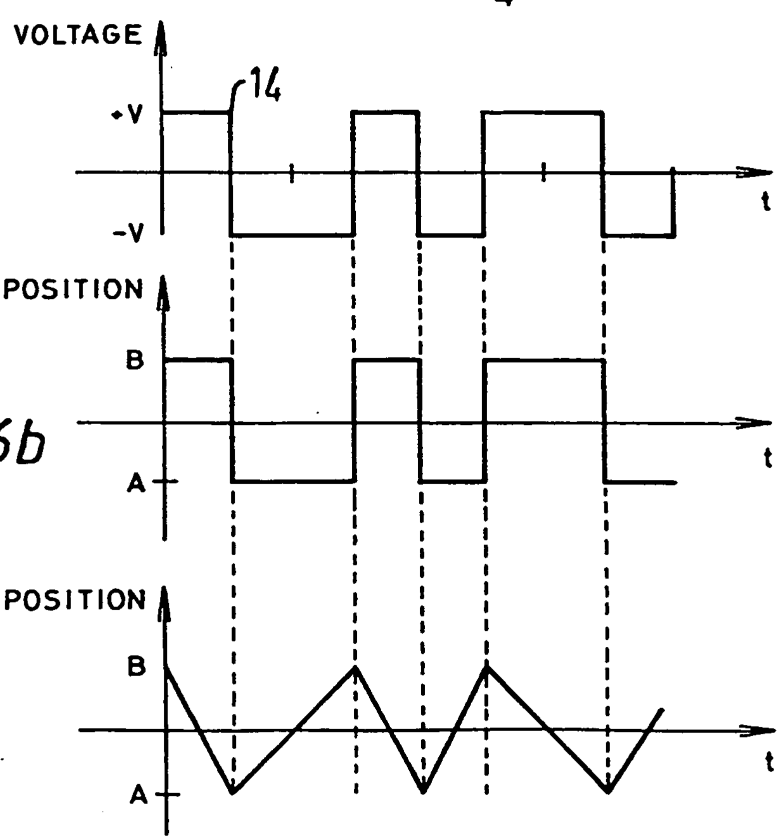


FIG. 17

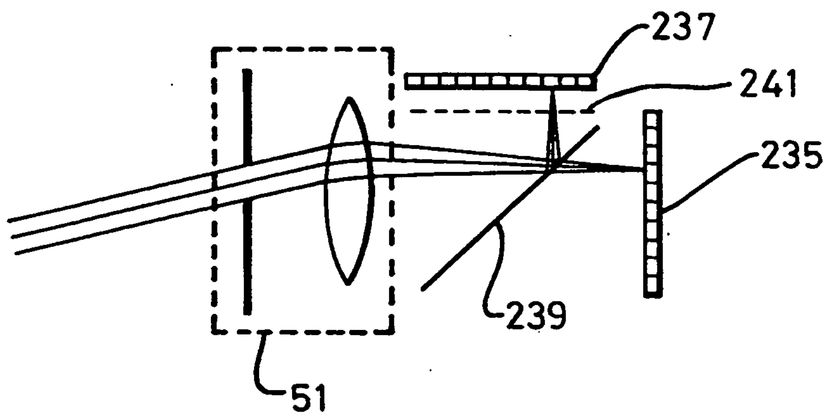
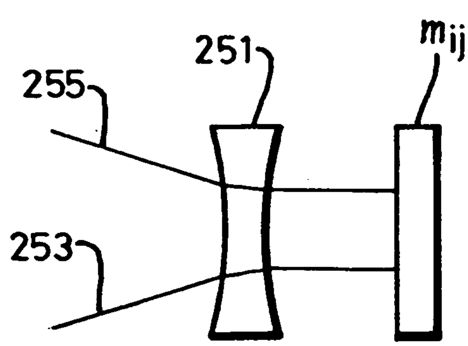


FIG. 18



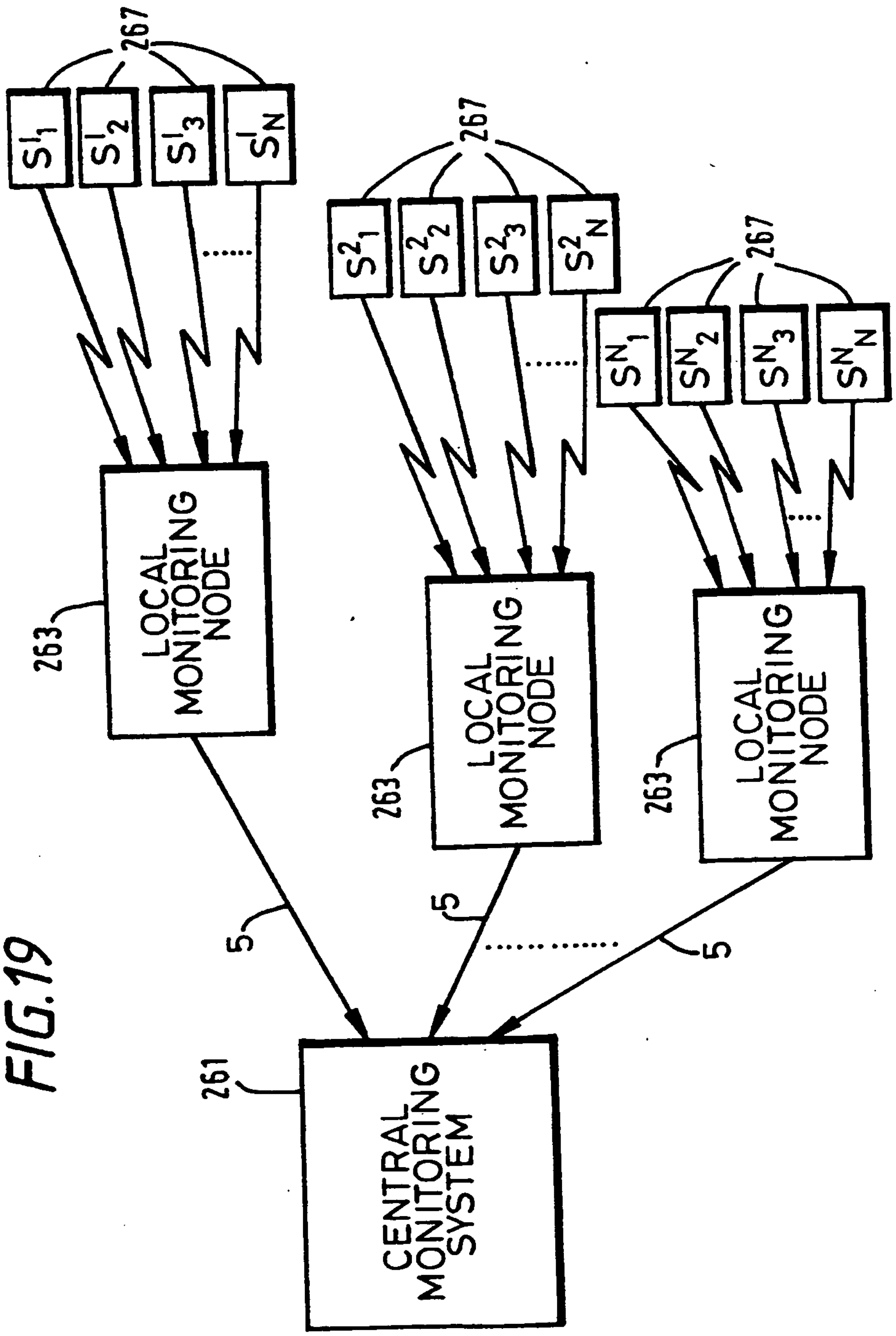

267
S^1_1
S^1_2
S^1_3
S^1_N
267
S^2_1
S^2_2
S^2_3
S^2_N
267
S^N_1
S^N_2
S^N_3
S^N_N
263
LOCAL MONITORING NODE
263
LOCAL MONITORING NODE
263
LOCAL MONITORING NODE
5
5
5
261
CENTRAL MONITORING SYSTEM

FIG.19

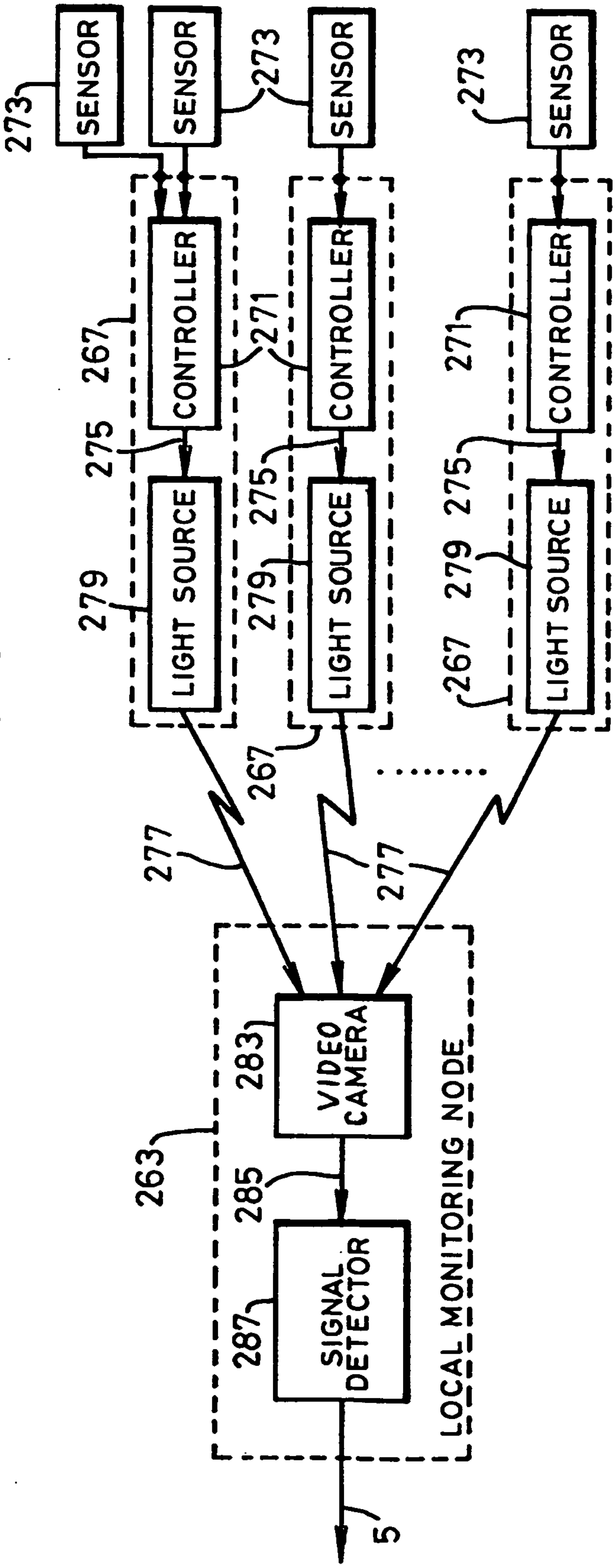

SENSOR
SENSOR
SENSOR
SENSOR
273
CONTROLLER
CONTROLLER
CONTROLLER
LIGHT SOURCE
LIGHT SOURCE
LIGHT SOURCE
267
271
275
279
277
VIDEO CAMERA
283
285
SIGNAL DETECTOR
287
263
LOCAL MONITORING NODE
5

FIG. 20